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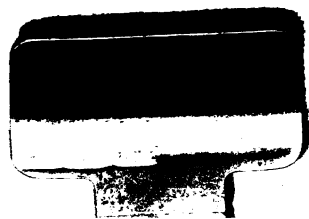
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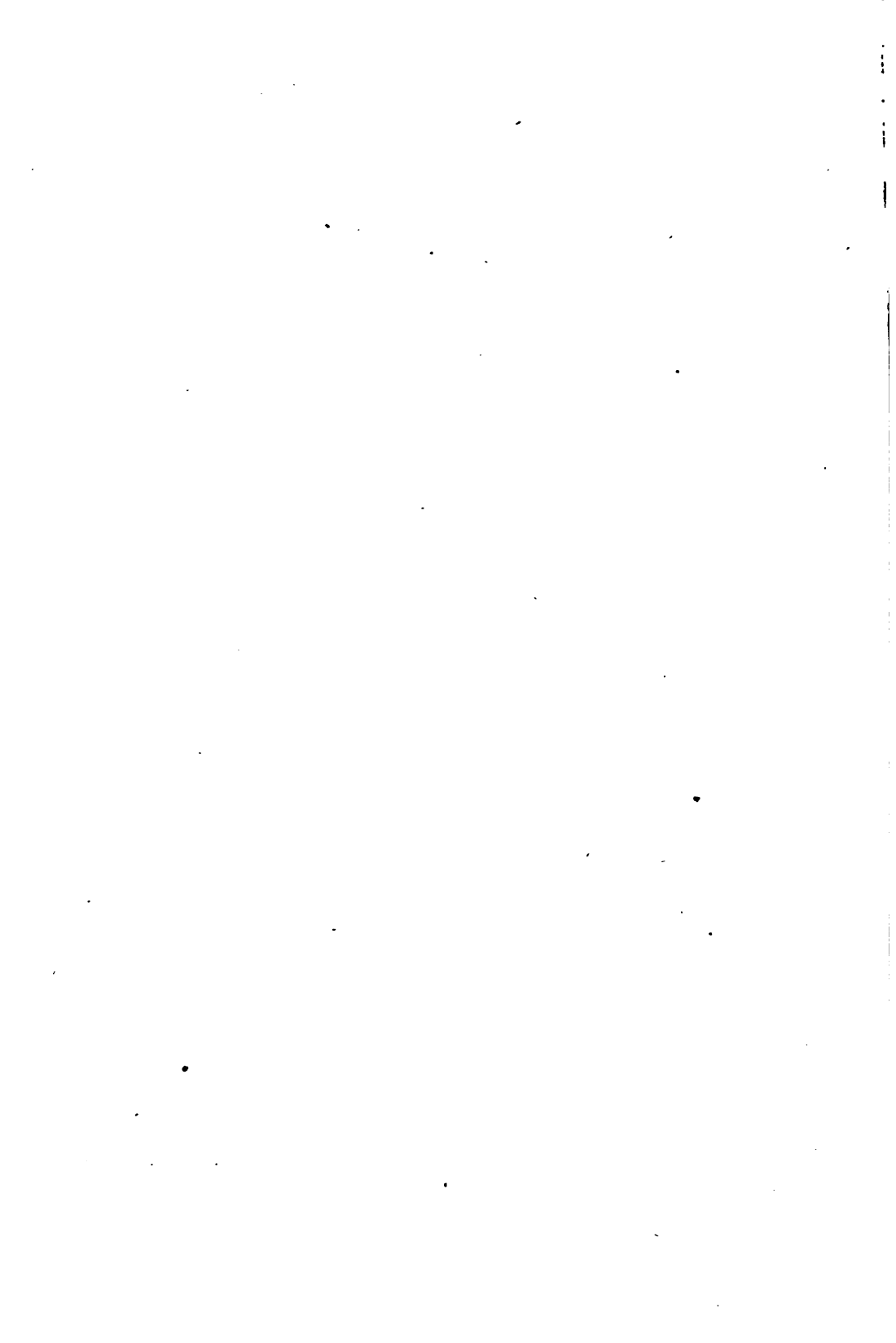
HYDRAULIC  
ELEVATORS



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# HYDRAULIC ELEVATORS

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BY WILLIAM BAXTER, JR.,

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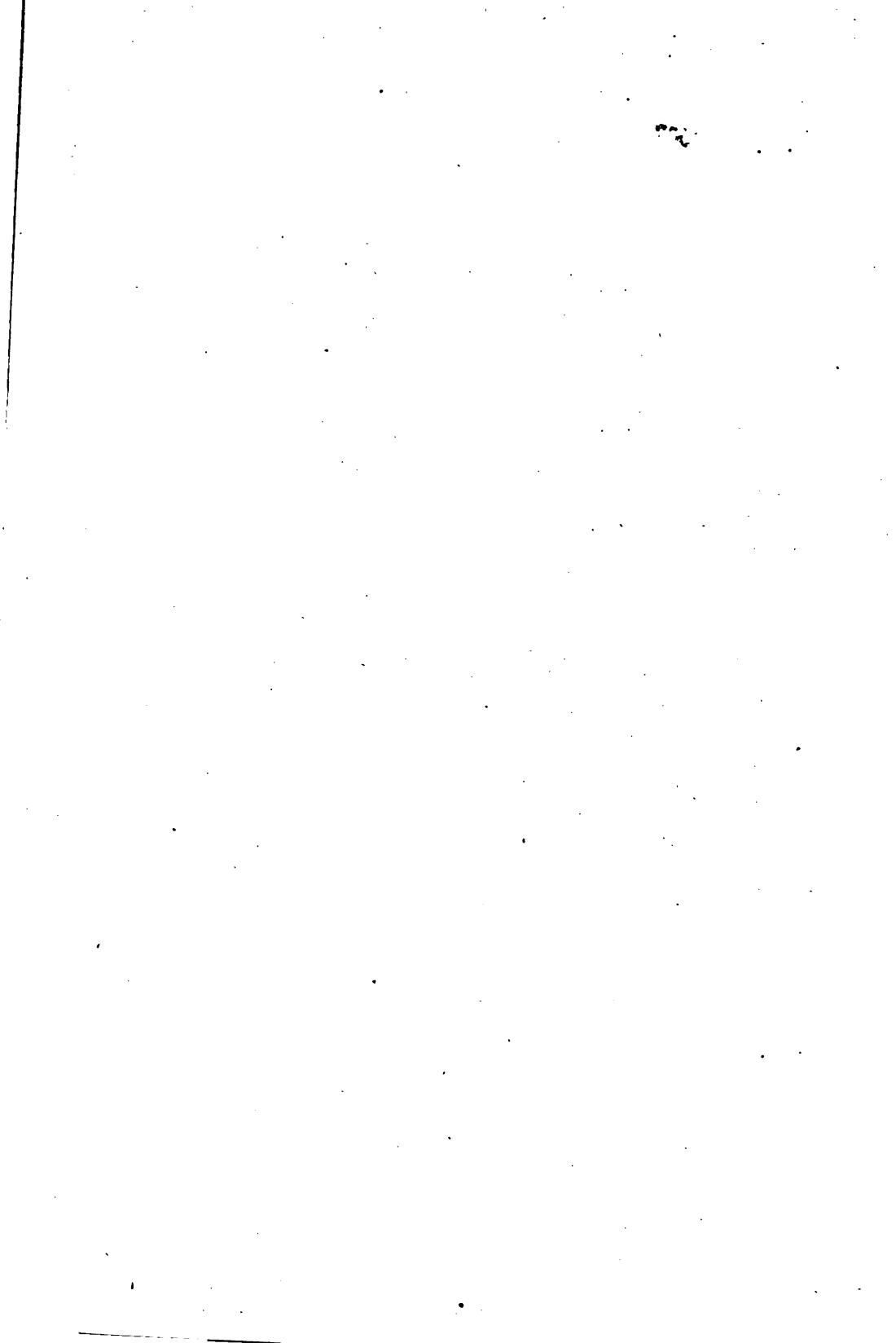
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# HYDRAULIC ELEVATORS.

## CHAPTER I.

### THE VERTICAL HYDRAULIC ELEVATOR—SHEAVE AND ROPE ARRANGEMENT METHODS OF CONTROL.

**B**RIEFLY explained, the mechanism of a hydraulic elevator consists of a cylinder and piston, and suitable valves for controlling the flow of water into and out of the cylinder so as to cause the piston to move from one end to the other and back again. By means of one or more piston rods, the motion of the piston is transmitted to a cross-head which, in turn, moves the lifting ropes from which the elevator car is suspended. The hydraulic cylinders are made either vertical or horizontal, and the connection between the piston crosshead and the lifting ropes may be made such that the car moves either at the same velocity as the piston, or several times faster. In almost every case, however, the motion is multiplied, so that the car travels from two to twelve times as far as the piston.

Vertical-cylinder, hydraulic elevators are used in all cases where floor space is restricted, and horizontal machines in cases where space for the accommodation of the cylinders of vertical machines above the basement floor cannot be conveniently obtained. In buildings where there is no restriction as to space, vertically or horizontally, the use of either type of cylinder is a matter of individual choice.

Vertical-cylinder elevators are generally geared from two to one, up to six to one, ratios of three and four to one being, probably, the most common. Horizontal cylinders are seldom made of lower gear than six to one, and are frequently made of as high gear as twelve to one. Fig. 1 shows, in perspective, the general arrangement of a vertical-cylinder elevator geared four to one. The general arrangement of a modern vertical-cylinder, hydraulic elevator geared two to one is shown in Fig. 2, p. 6.

Following the lifting ropes from the top of the car, over the two overhead sheaves, it will be seen that they pass down and under a sheave *A* attached by means of the strap *B* to the crosshead *D* of the hydraulic cylinder. The ends of these lifting ropes are fastened to the overhead beams. With this arrangement, it will be seen that, if the sheave *A* is drawn downward 10 feet, the elevator car will be lifted 20 feet, thus

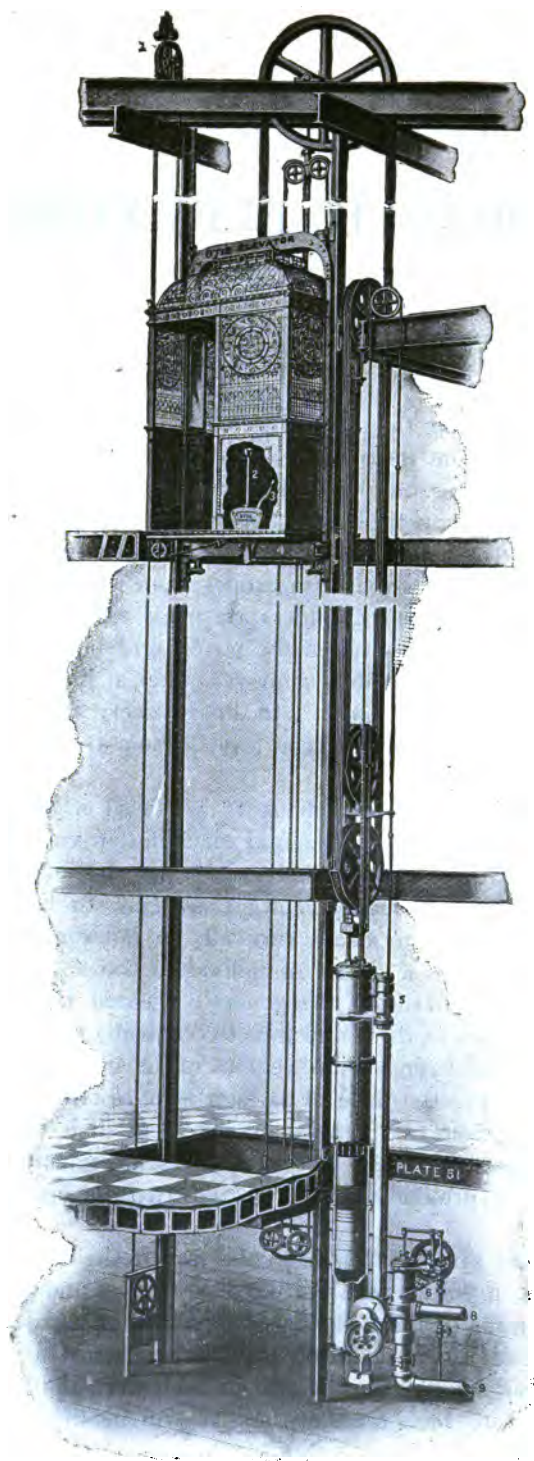


FIG. I.

making the speed of the car, as well as the distance it traverses, twice as great as that of the piston *F*.

To make the gear ratio three to one, another sheave is provided located above *A* and secured in a stationary position by means of suitable supports. This sheave is not located on the same level as the overhead beams if it can be conveniently placed lower down, for with a three-to-one gear the sheave *A* will rise to a height equal to a trifle more than two-thirds of the height of the elevator well. The ends of the ropes in a three-to-one gear are attached to the top of the strap *B*.

For a four-to-one gear, in addition to the stationary sheave above *A*, there are two sheaves carried by the strap *B*, one above the other, and the lifting ropes pass first around the lower one, thence up and over the stationary one, and down again and around the upper traveling sheave, the ends being secured to a stationary support under the stationary sheave.

In former days, when elevators ran at moderately fast speeds, from 100 to 250 feet a minute, the valve gearing used to control the flow of water into the lifting cylinder was simple, but with modern high-speed elevators this simplicity cannot be retained. If the elevator car runs not faster than about 250 feet a minute, the operator can readily control the movement of the car by pulling upon a hand rope, but when the velocity is increased, certainty of operation cannot be depended upon if the hand rope is employed. As can be easily realized, if the hand rope is slipping through the operator's hand at a velocity of 5 or more feet a second, and he grips it a fraction of a second too soon or too late, the car will not be stopped at the proper point.

To do away with the uncertainty of operation arising from the use of the hand rope in high-speed elevators, lever and wheel-operating devices have been developed. But to make these devices operative the operating valves have been modified. The main valve, that controls the flow of water into and out of the hydraulic cylinder, varies from about 3 inches in diameter, in small machines, to 7 or more inches in the largest sizes. These valves are made tight by the use of cup packing, and as the pressure of the water forces the packings out against the sides of the valve chamber, the force required to move the valves is considerable—ranging from probably 40 pounds in the smaller sizes up to 150 or more in the largest size. The stroke of the valve is only a few inches each way from the central position; therefore, if the valve is moved by means of a hand rope, the pull on the rope can be reduced by making the connection between the rope and valve such that the former may be pulled through a distance of several feet to throw the latter wide open.

Thus, if the valve is moved 4 inches, by pulling the hand rope

through 40 inches, the force exerted upon the rope will be one-tenth of that required to move the valve if pulling directly upon the valve stem. The type of valve used for simple hand rope control will be shown hereafter; for the present we will confine ourselves to an explanation of Fig. 2, which illustrates a modern type of high-speed elevator.

Sidewise movement of the lever located at  $L$  controls the movement of the car. The swinging of  $L$  to one side or the other rocks the horizontal lever  $M$ , and this motion causes the sheave  $P$  mounted on the frame  $I$  to rotate through a small angle. The rotation of  $P$  is transmitted to  $P'$  through the rope  $k$ , and the rotation of  $P'$  actuates the valves in a manner that will be presently explained.

Ropes  $m m$ ,  $n n$  pass around sheaves  $N N N N$  located at top and bottom of the elevator well, as is clearly shown. The ends  $m m$  are fastened to the ends of the lever  $M$  but the sides  $n n$  are not connected with it, although in the drawing they look as if they were. The side  $n$  that runs up from the right-hand side  $N$  sheave at the bottom passes over the  $N$  sheave at the left-hand side at the top of the elevator well. These two  $N$  sheaves at the top are mounted upon a frame  $I$  which is arranged so as to hold the sheaves firmly in the horizontal position, but allows them to revolve freely around the studs upon which they are mounted. The frame  $I$  is suspended from a rope that passes over the two small sheaves resting on top of the overhead beams. The end of this rope extends downward, outside of the elevator well, and has a weight suspended from it so as to hold the ropes  $m m$ ,  $n n$ , with the proper tension.

Upon the larger sheave  $P$  are mounted the lower  $N N$  sheaves. If the right-hand end of lever  $M$  is depressed, the right-hand loop formed by the rope  $n m$  will be lowered, while the left side end will be raised, and as a consequence the right side lower  $N$  sheave will swing downward while the left side one will swing upward. Thus the rope  $k$  will be pulled with the upper side moving from left to right, and sheave  $P'$  will be rotated in the direction in which the hands of a clock move.

This arrangement of ropes for transmitting the motion of lever  $L$  to sheave  $P'$  is called the running rope system. There is another way of accomplishing the result with stationary ropes, the upper ends of these being attached to the upper frame  $I$  and the lower ends to the sides of sheave  $P$  or to the ends of a lever secured to this sheave. In this arrangement the rope that is fastened to the right-hand side of sheave  $P$  is secured to the left side of the upper frame  $I$ . The sheaves  $N N N N$  are placed upon the ends of lever  $M$  and each rope passes over one sheave at one end and under another sheave at the other end of  $M$ . This is the standing rope system. For both systems there are several modifications,

but they all accomplish the same result—namely, to transmit the motion of lever  $L$  to sheave  $P'$ .

The valve that controls the flow of water into and out of the hydraulic cylinder is marked  $v$ . As already stated, this valve cannot be moved without the application of a considerable force. The piston  $T$  located in the enlarged portion of the valve chamber is for the purpose of providing this moving force. As will be seen, piston  $T$  is larger in diameter than valve  $v$ ; therefore, if water under pressure is admitted into the space between  $T$  and  $v$ , the excess of pressure on the under side of  $T$  over that on the upper side of  $v$  will carry it upward, provided there is no pressure on the upper side. If water under pressure is admitted on top of  $T$ , as well as under it, then the forces acting to move it will be balanced and there will be no tendency for the valves to move up or down, insofar as the pressure acting upon  $T$  is concerned. The valve  $v$ , however, will have the pressure of the water acting upon its upper side, while the lower side will be held up only by the pressure of the atmosphere or that of the tank into which the water is discharged; hence, the valve will be depressed.

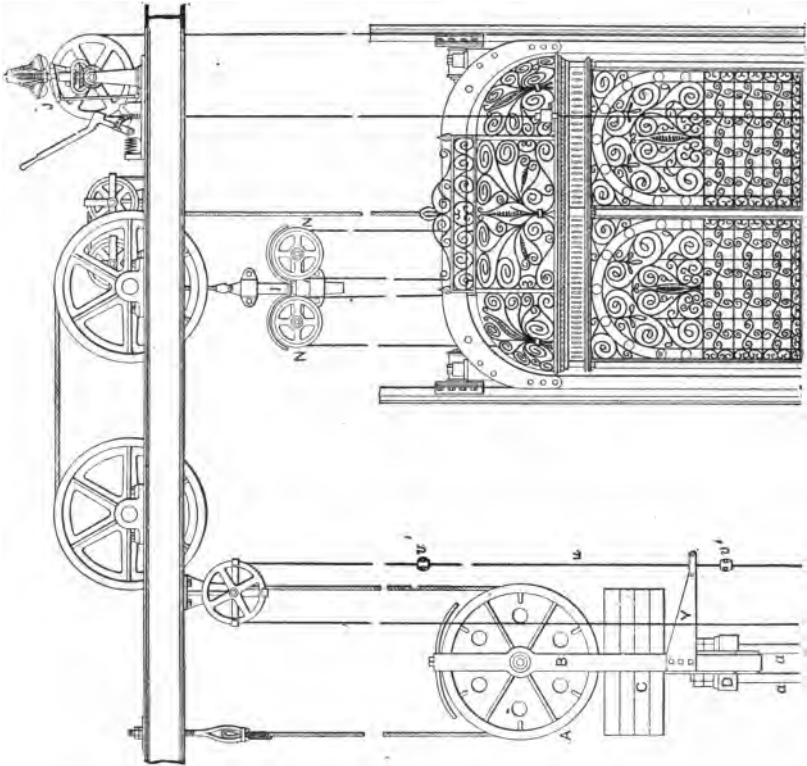
At  $h$  a small pilot valve is placed, and this is connected with the pressure pipe through the pipe  $g$ , and by means of another pipe  $f$  it is connected with the space above piston  $T$ . When the elevator is at rest, the pilot valve  $h$  is in a position to close the ports that connect with the pipes  $g$  and  $f$ , and also prevents the escape of water into the larger pipe that runs to the main discharge pipe from the lower end of the pilot valve chamber. Under these conditions, the water in the main valve chamber, above  $T$ , is locked in and cannot escape unless the valve  $h$  leaks. The valve  $V$  is called a throttle valve, and is used for the purpose of preventing a violent stop of the piston in the main cylinder  $E$  in slowing down. This valve closes the communication between the supply pipe and pipe  $G$ . It is not used in all elevators.

When sheave  $P'$  is rotated in a clockwise direction, the crank on the end of the shaft will draw down the connecting rod  $j$ , and as the valve  $h$  can move much easier than the main valve  $v$  and piston  $T$  the latter will remain stationary while  $h$  will be depressed. This movement of  $h$  will uncover the ports connecting with pipes  $g$  and  $f$ , and thus a through connection will be established between the pressure pipe and the upper end of the valve chamber, and water under pressure will flow into the space above  $T$  and force the latter downward.

This downward movement will carry the throttle valve  $V$  down so as to uncover the port connecting with pipe  $G$ , and it will also move the main valve  $v$  far enough down to uncover the upper edge of the port connecting with the lower end of the cylinder, thus opening a communi-

cation between the two ends of the main cylinder. Under these conditions the weight of the elevator car which acts to pull piston *F* upward will set the latter in motion, and the water in the upper end of the cylinder *E* will be forced down through pipe *G* and through the valve chamber, around valve *V* into the lower end of the cylinder. The pipe *G* is called a circulating pipe, as one of its objects is to provide a path through which the water may circulate between the top and the bottom of the cylinder *E*.

As the action just explained takes place when the elevator car



descends, it will be seen that, for the down trip, no water is drawn from the pressure tank. To run the car upward, the sheave *P'* is rotated counter clockwise by swinging the car lever *L* in the opposite direction. When *P'* is so rotated, the crank on the end of the shaft will push connecting rod *j* upward, and thus pull on rod *i* and thereby lift the pilot valve *h*. The upward movement of *h* uncovers the port that connects with pipe *f*, but keeps that connecting with pipe *g* closed, so that the water confined in the valve chamber above *T* can now escape through

pipe *f* and the lower end of the pilot valve chamber into the discharge pipe.

In this way the pressure acting on the upper side of *T* is removed, and the pressure acting on the lower side forces the valves upward owing to the difference in area between piston *T* and valve *v*. The upward movement of valve *v* opens communication between the port running to the lower end of the hydraulic cylinder and the discharge pipe, so that the water in the lower end of the cylinder can now escape into the discharge pipe and thus reach the discharge tank.

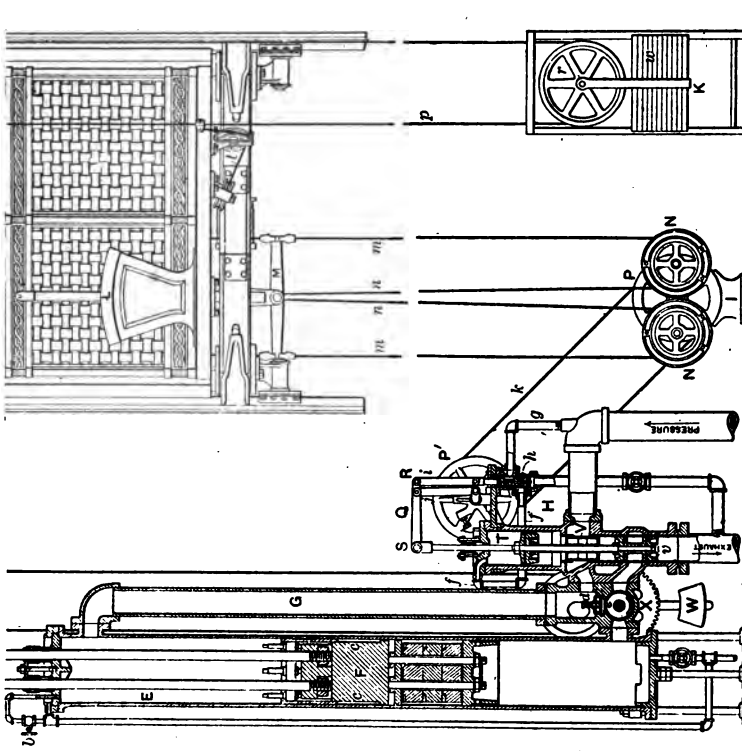


FIG. 2.

This upward movement of the valves also raises the throttle valve *V* and gives the water from the pressure pipe free access to the port connecting with the pipe *G*, thus admitting a new supply of water under pressure to the upper end of the hydraulic cylinder. Under these conditions, the water under pressure acting upon the upper side of the piston *F* in conjunction with the vacuum that tends to form under the piston by the escape of the water into the discharge pipe provides the force that depresses the piston and thereby lifts the elevator car.

Upon the rapidity with which the water can enter or pass out of the

cylinder will depend the velocity with which the piston will move, and this rapidity of flow is evidently dependent upon the extent to which the valves are opened. If the operator in the car desires to run at a slow speed, he moves lever  $L$  a short distance from the central position; for a higher speed, he moves it further from the center, and for the highest velocity, he moves it as far as it will go.

Now suppose  $L$  is moved a short distance only, then sheave  $P$  will be rotated through a short angle, imparting a correspondingly small movement to connecting rod  $j$ . Suppose  $j$  is depressed, thus opening the connection between pipes  $g$  and  $f$ . Water will begin to flow into the space above  $T$  as soon as the pilot valve  $h$  moves down far enough to uncover the ports connecting with pipes  $g$  and  $f$ , and draw down the end  $S$  of lever  $Q$ . As  $j$  will now be stationary, it will act as a fulcrum, and thus end  $R$  will be lifted. This motion will continue until pilot valve  $h$  is raised far enough to cover the ports connecting with pipes  $g$  and  $f$ , and thus stop the flow of water into the space above  $T$ .

Thus it will be seen that after the pilot valve  $h$  has been moved by the rotation of the sheave  $P'$  the main valve  $v$  and piston  $T$  begin to move, and as they move they carry the pilot valve back to the stop position. If the pilot valve is moved only a short distance from the stop position, the piston  $T$  and valve  $v$  will have to move only a correspondingly short distance to return the pilot valve to the stop position; hence, it can be seen that, if the car lever  $L$  is moved a short distance so as to open the pilot valve only a portion of the full stroke, the main valve will open only a portion of the full stroke; therefore, the opening of the main valve is directly in proportion to the movement of the operating lever  $L$ , just as much as if this lever were attached directly to the valve  $v$ .

As water is practically incompressible, it can be readily seen that, if the car lever  $L$  is moved rapidly to the central position when the car is running at a high velocity, the motion will be arrested with a violent jerk. To prevent such action, means are provided whereby the water may find an outlet, if the valve is closed too suddenly. If the sudden stop occurs on the downward trip of the car, which is the up stroke of piston  $F$ , the water will leak by the throttle valve  $V$  and flow back into the pressure pipe, and will continue to flow until the car has come to a stop.

If the throttle valve  $V$  were not provided, the water would escape too freely back into the pressure pipe, and as a result the car could not be stopped in a very short distance; hence, the object of valve  $V$  is to provide means to prevent a too sudden stop of the car on the down trip, and at the same time not to permit the car to run farther

than is necessary to make a gradual stop. Valve  $V$  is not a water-tight fit, and its ends are tapered off so that its throttling action may begin gradually.

If the car is stopped too suddenly on the up trip, the water in the lower end of cylinder  $E$  will be forced through the valve  $d$  at the bottom of the circulating pipe  $G$ , and the momentum of the moving parts will be expended in compressing the spring that holds  $d$  down upon its seat.

As elevator operators are liable to forget to stop the car before it reaches the end of its travel, in either direction, it is necessary to provide means for stopping it automatically; otherwise it would occasionally run into the overhead beams or strike violently against the bottom of the well. The valve  $e$  placed in the passage from the valve chamber to the lower end of the hydraulic cylinder is for this purpose. This valve is shown in its normal position, in which it is held by the weight  $W$ . There is a gear wheel  $X$  mounted upon the shaft that carries valve  $e$ , and this gear meshes with a smaller one mounted upon the same shaft with the sheaves around which the rope  $u$  passes. This rope is provided with stop balls  $v' v'$  which are struck by an arm  $Y$  that projects from the piston crosshead  $D$ . In the drawing these stop balls appear to be placed close together, but in reality they are far apart, one being very near to the highest point reached by arm  $Y$ , while the other is equally near to the lowest point reached by  $Y$ ; hence, they are not struck by  $Y$  until it reaches almost the limits of its travel. Generally these stop balls are set so that the car will stop automatically a few inches above the upper landing and a corresponding distance below the lower landing.

The governor seen at the upper right-hand corner of the drawing is a safety device to stop the car, if, from any cause, it should run away. Those who are not familiar with the operation of elevators are generally inclined to believe that, if a car is provided with two or more lifting ropes, it is practically safe. This conclusion is arrived at from the fact that it is hardly possible for all the ropes to give away at the same time, and most people suppose that the only way in which a car can fall is by the breaking of the lifting ropes.

As a matter of fact, very few elevator accidents are caused by the breaking of the lifting ropes. The principal danger arises from some disarrangement of the mechanism which permits the car to attain a dangerous velocity. There are many ways in which the speed can become dangerously high, although all of them are next to impossible in well constructed machines; but as all things human are liable to fail, it is necessary to provide all possible safeguards. As an illustration of how a car may run away, we may mention springing of a leak in the hydraulic cylinder, or blowing off one of the cylinder heads, or bursting of pipe  $G$ ,

all of which are highly improbable accidents, but not actually impossible.

As will be seen by following the rope that drives it, the safety governor is connected with safety clamps generally attached to the under side of the car, although in some instances they are on top. If the speed of the car becomes too great, the rope that drives the governor is gripped by jaws provided for that purpose, and then the end secured to the safety device under the car throws this into action and the car is firmly clamped against the vertical guides upon which it runs.

The governor rope  $p$  runs under a sheave  $r$  at the bottom of the elevator well, this sheave being carried in a weighted frame as shown at  $K$ , and  $w$ , the weight, being sufficient to insure the perfect operation of the governor.

## CHAPTER II.

## VALVE CONSTRUCTION AND OPERATION OF THE OTIS VERTICAL HYDRAULIC ELEVATOR.

**I**N THE previous chapter an illustration is given showing the general arrangement of the various parts of a modern, high-speed, hydraulic elevator with vertical cylinder. This cut shows what is generally called a low-pressure machine. In this chapter we will consider more fully the details of construction.

Details of the main valve are shown in the drawings, Figs. 3 to 7. Fig. 3 is a vertical elevation in section of the valve and valve chamber. Fig. 4 is a horizontal section of Fig. 3 taken on the line *AB*. Fig. 5 is a similar horizontal section of Fig. 3 taken on line *CD*.

The valve consists of the part *H*, which is the valve proper, and the piston *G*, both of which are mounted upon the rod *J*. The office of piston *G* is to move valve *H*, the entire apparatus being called a differential valve, because it is moved up and down by the difference in the pressure acting on the two parts *H* and *G*. By referring to Fig. 2, it will be seen that the left side of Fig. 3 is bolted against the hydraulic cylinder, and that the supply pipe from the pressure tank is attached to the seat around port *K*.

When in the stop position, as shown in Fig. 3, the throttle valve *I* covers the port *K* leading to the supply pipe, and also the port *L* leading to the circulating pipe that runs to the upper end of the hydraulic cylinder. This throttle valve is not a perfectly tight fit, so that water can leak through it in sufficient quantity to keep the space in the valve chamber between valves *G* and *H* full and under the same pressure as the supply pipe. At first glance, it might seem that this arrangement would represent a loss by leakage, but it does not, for although water can pass slowly through the throttle valve and into the upper end of the hydraulic cylinder, it can go no farther until the piston in the cylinder moves, and this piston cannot move until valve *H* uncovers port *M*.

Valve *H*, as will be noticed, is provided with leather cup packings and is perfectly watertight, so that, when it is in the stop position, no water can escape from the lower end of the hydraulic cylinder. The throttle valve *I* can be removed entirely without interfering with the operation of the elevator, if the speed at which the car is run is low. When the car is running down, the piston in the hydraulic cylinder is moving upward, and the valve *H* is below the position shown in Fig. 3,

so that the water from the upper end of the hydraulic cylinder can run into the valve chamber through port *L*, and into the lower end of the cylinder through port *M*. If the valve *H* is raised so as to cover port *M* instantly, the water flowing into the valve chamber through port *L* will have no way of escape except through the pressure pipe attached to port *K*. If the speed of the elevator car is low, its momentum will not be sufficient to force any considerable amount of water back into the pressure pipe, for, in addition to the resistance set up by the pressure in the pipe, there is a back suction set up in the hydraulic cylinder because the valve *H* prevents the entrance of water to the lower end.

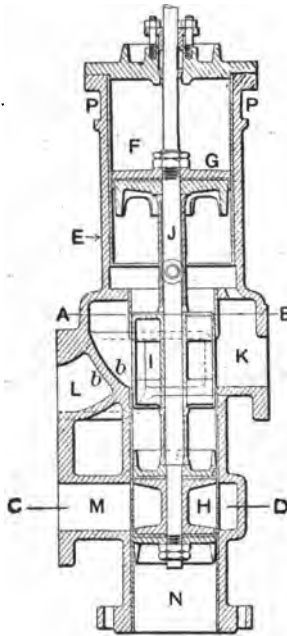
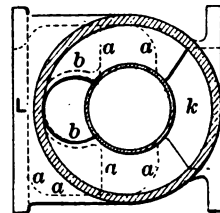
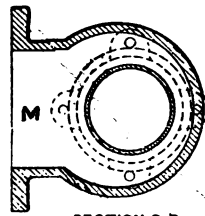


FIG. 3.



SECTION A-B



SECTION C-D

FIG. 4. FIG. 5.

Thus it will be seen that, if the piston in the hydraulic cylinder moves upward any distance, after valve *H* has been moved to the stop position, it will form a vacuum on the under side, in addition to forcing a certain amount of water back into the pressure pipe. If the car speed is low, the momentum of the moving parts will not be sufficient to move the piston more than a short distance, even if the throttle valve *I* is removed. If, however, the car speed is great, the car may run a considerable distance after valve *H* is moved to the stop position, if the flow of water through the valve chamber, from port *L* to port *K* is unob-

structed; but if the throttle valve *I* is interposed, the flow of water is hindered. This throttle valve *I* is tapered for a considerable distance at each end, so as not to check the flow of water too suddenly, and when an elevator is first installed, if it is found that the action of the throttle is too rapid, grooves are filed in the taper ends until the leakage is sufficient to give a perfectly smooth motion of the car in stopping.

Space *F* in the valve chamber above *G* is filled with water through the pilot valve, as fully explained in the previous chapter. When the valve *H* is in the stop position, as shown in Fig. 3, the pilot valve is also in the stop position and thus the water above *G* is locked in and the valves *G* and *H* cannot move, for the upward movement could not be effected without compressing the water in space *F*, and the downward movement could not be effected without forming a vacuum in this space. When the pilot valve opens communication between the space *F* and the pressure pipe, the pressure acting on the upper side of *G* becomes equal to that acting on the under side, thus balancing the up and down forces acting on *G*; but at this same instant, the downward force acting on top of *H* is greater than the upward force, as the pressure of the supply pipe acts on top, while the pressure on the under side is simply that of the discharge pipe. Thus the excess of pressure on the upper side of *H* forces the valves downward.

When the pilot valve opens communication between space *F* and the discharge pipe, the pressure on the upper side of *G* is removed, and then, as the diameter of *G* is greater than that of *H*, the force acting to push *G* upward is greater than the force acting to push *H* downward, and, as a result, the valves are moved upward.

Port *K* opens into the valve chamber at two points diametrically opposite as can be clearly understood from the section Fig. 4. In this drawing the lines *a a a a* represent the outline of port *L*, and lines *b b* are the outlines of port *K* on the left side of the valve chamber. Port *K* runs over the top of port *L* on the sides of the valve chamber and dips down into the depression formed by lines *b b* as shown plainly in Fig. 3. The port *M*, as is shown in Fig. 5, completely surrounds the valve chamber. The valve chamber is provided with brass linings so that the surfaces over which the valves move may remain bright.

As valve *H* is provided with cup packings, and these cannot pass over open ports without being caught, the brass lining opposite port *M* is perforated with a large number of small holes, the number of these being sufficient to permit the water to flow through with as little resistance as possible. The packings in valve *H* are set so as to withstand pressure acting from above and the packing in valve *G* is set in the opposite direction, so as to resist pressure acting from below. These

packings are replaced by removing the valve rod through the upper end of the valve chamber.

The pipe that connects the upper end of the valve chamber with the pilot valve is screwed into an opening cast in the top head of the valve chamber. This head is shown in detail in Fig. 6, in which the port hole to which the pilot valve pipe is attached is marked *A*.

Fig. 7 shows the frame upon which the pilot valve and the operating hand sheave are supported; this consists of two parts, the main frame *A* and the clamping strap *B*. This frame fits around the upper end of the valve chamber, in the groove shown at *PP* in Fig. 3. The pilot valve drops into the hole shown at *C* in Fig. 7, and the operating sheave supports are secured to frame *A* in the space between the main valve and pilot valve, being secured by means of bolts passing through the eight holes shown.

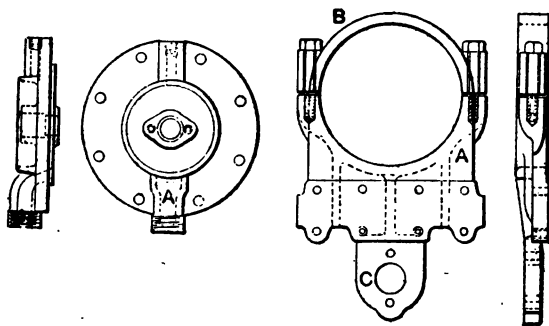


FIG. 6.

FIG. 7.

In old-style elevators in which the operating valve is moved by direct pull upon a hand rope passing through the car, the pilot valve is not used, the operating sheave being mounted upon a shaft that carries a pinion that meshes into a rack attached to the upper end of the main valve stem. This construction will be understood from Fig. 8, which is a vertical section of the old style valve. As will be seen, the rack *B* forms an extension of the upper part of the top valve *E*. The pinion *C* is mounted upon the shaft *D*, upon one end of which the operating sheave is placed. The guide *N* holds the rack *B* in mesh with the pinion.

In Fig. 8 it will be noticed that the lower valve *F* and the upper valve *E* are of the same diameter. The only object of *E* is to balance the pressure acting upon *F*, so that the force required to move the valve may be the same whether it is moved up or down. The valve *E* is provided with a cup packing, and is intended to be water tight, but should it leak

slightly, the water passing into the space above it can find an outlet through the hole seen in the center casting *R*. The joints at *L* and *S*, as well as around shaft *D*, need not be packed, as it is not supposed that

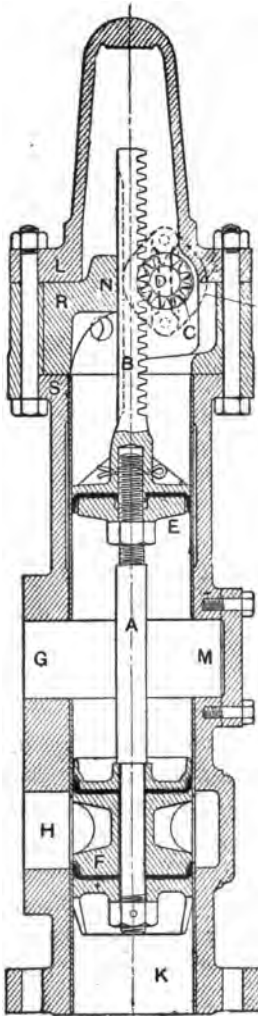


FIG. 8.

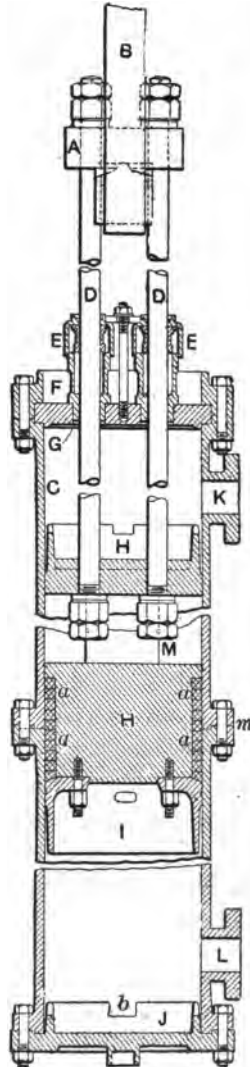


FIG. 9.

water will escape into this space, and if it does it is necessary that it find a free outlet, so as not to develop a pressure on the upper side of valve *E*.

It is for this reason that an outlet is made in casting *R*. In this way

the atmospheric pressure acts on the top of valve *E* and on the under-side of *F*, while the tank pressure acts on the upper side of *F* and under side of *E*, and as both valves are of the same size, the pressures are perfectly balanced.

In Figs. 9-11 are shown the hydraulic cylinder and piston in detail. Fig. 9 is a vertical elevation in section of the cylinder with piston, piston rods and crosshead in position, and the other two figures show the piston and the follower that serves to hold the packing in place. The cylinders vary in length from 10 to 40 feet, according to the height of the building and gear of the machine. When longer than 12 feet, they are made in sections and are bolted together as shown at *m* in Fig. 9.

At the upper end, the cylinder is closed by means of two pieces, one marked *G* being the head proper, and the other marked *F* being a clamping ring to hold *G* in place. If a single head were used, considerable trouble would be experienced in getting the stuffing boxes *EE* for the piston rods, in the proper position, owing to the fact that the cylinder must be set in such position as the conformation of the building will permit, while the piston rods and cross-head *B* must be in such position as the space in which the lifting ropes run may require. By making head *G* separate from *F*, the cylinder can be set in any position required, and then *G* is twisted around so as to bring the cross-head in the proper position with respect to the lifting ropes.

The valve chamber is attached to the lower port *L* of the cylinder but not directly. By looking at Fig. 2 it will be seen that there is an intervening casting between the cylinder and the valve chamber, which carries the relief valve for the lower end of cylinder, and also the valve that effects the automatic stop of the car at the top and bottom landings.

The piston packing is placed at *aa* and consists either of square rubber or hemp rope, the latter being regarded as the more desirable. In some of the old types of pistons, the packing consists of a leather cup about 5 inches deep surrounded by three or four rings of square rubber packing. Holes are provided through the inner sides of the piston so as to allow the water to get behind the cup packing and force it outward, thus pressing the rubber rings against the side of the cylinder. At the present time, the long stuffing box as shown in Fig. 9 with hemp rope packing is regarded as more effective.

Stuffing boxes for the piston rod are similar in construction to those used in steam engines, pumps and like machines, the only unusual feature being a locking plate which guards effectually against the working loose of either one of the compressing caps.

In Fig. 10 the main part of the piston which is marked *H* in Fig. 9

is shown separately, the lower view being a vertical section at right angles to the view in Fig. 9. As will be noticed, there is an open space between the top and bottom of the casting, into which the ends of the piston rods project and are secured in position by means of nuts, as shown at *M* in Fig. 9. The parts *B B*, Fig. 10, which connect the top and bottom parts of the piston are shown in broken lines at *B B* in the plan. The piston rods pass through holes drilled at the points *C C*. The follower which compresses the packing *a a* in the piston, Fig. 9, is shown in Fig. 11.

In Fig. 9 it will be noticed that the piston is tapered for a considerable distance at each end, and it will also be seen that the flange projecting upward from the lower cylinder head has depressions at *b*. This

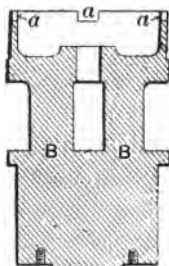
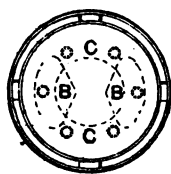


FIG. 10.

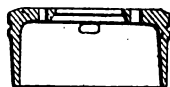


FIG. 11.

construction is used so as to permit free access of the water to the upper or lower side of the piston, when the latter is close up to either end of the cylinder. If it were not for this construction, the car would move slowly when starting from either end and would not attain full speed until the piston passed the ports *K* or *L*.

The piston shown in Fig. 9 is packed from the lower end of the cylinder, but a piston is also designed so as to be packed from the upper end. Such a piston is shown in Fig. 2. When the piston is packed from the upper end, the car is lowered until it rests firmly on the buffers at the lower landing, while the packing is being put in place, and if the piston is packed from the lower end, the car is run up as far as necessary and is firmly secured to the overhead beams. In either case the repacking of a piston is a considerable job.

## CHAPTER III.

## MAGNETIC CONTROL FOR HYDRAULIC ELEVATORS.

OPERATING hydraulic elevators by means of a lever or hand wheel in the car, while entirely satisfactory when judged from the present state of the art, is not wholly free from objections. The ropes that connect the car lever or wheel with the valve gear are subject to a constant stress, and, as a result, will continuously stretch from the first day they are used until they wear out. In all arrangements used for transmitting the motion of the car lever or hand wheel to the valve gear, two ropes are required and as can be readily realized, these are not likely to stretch alike.

If the elevator well is 150 or 200 feet high, each one of these ropes will be from 300 to 400 feet long, so that a slight inequality in the stretching quality of the two ropes will make a difference of an inch or two in the total elongation. The result of this inequality will be that the car lever will not come to the central position when the valves are closed and the car is stopped.

This disturbance in the adjustment will not, of itself, result in any special inconvenience, because the car operator will notice at once that the stop position of the lever has shifted from the center to one side or the other. If, however, the difference in elongation of the ropes is allowed to continue without readjustment, it will ultimately reach a point where it will be impossible to swing the lever far enough in one direction to open the valve wide and obtain the maximum car speed; while when the lever is swung in the other direction, there will be a considerable space to spare. When this stage is reached, it becomes necessary to tighten up the turnbuckle on the rope that has stretched the more, so as to restore the proper adjustment.

If some of the sheaves around which the ropes pass begin to run hard through improper attention, the result will be that one rope will be subjected to a greater strain than the other and thus the movement of the sheave wheel that operates the valves will not be in strict accord with the movement of the car lever. If the sheaves get into such condition that they run free and stick by turns, the operating sheave will swing back and forth owing to the fact that the elasticity of the ropes will respond to the inequalities in the resistance to rotation interposed by the sheaves around which they pass. This vibration of the operating sheave, if great enough, will result in imparting a pulsating motion to the car. To prevent these troubles, it is necessary to examine all the sheaves care-

fully and see that they run perfectly free at all times, and also to adjust the length of the two ropes so that when the car is stopped the lever will come to the central position.

In addition to the foregoing troubles, which are liable to be experienced with the lever or wheel operating systems, the apparatus is somewhat bulky and when placed in a car of small dimensions takes up room that cannot well be spared; the space required by the apparatus is further increased by the fact that the lever moves through a considerable distance, so that the operator must have a corresponding amount of elbow room.

Several attempts have been made to devise electromagnetic means for controlling hydraulic elevators from the car and quite a number of these are in use, although no system has been devised that is sufficiently perfect to drive the lever device out of the field.

Points of advantage possessed by a perfect electromagnetic controlling device are that the cumbersome lever in the car is replaced by a small electric switch and, as this can be manipulated with little or no effort, the operator requires less room to properly perform his work. Another advantage is that, when the connecting wires between the car switch and the valve actuating device are put in place and all the parts are properly adjusted, there is no danger of disarrangement by stretching or other causes. Still another advantage is that there are fewer moving parts to take care of, so that the apparatus will require less attention, and will be less liable to get out of order.

One of the simplest electromagnetic controlling devices for hydraulic elevators is illustrated in Fig. 12, which is a vertical elevation in section and a plan of the valve gear with the electromagnetic controller attached. The main and auxiliary valves are seen at the left and, in passing, we may call attention to the fact that in this case, the throttle valve shown in previous drawings of valves is not shown, on account of the use of the magnet controller, for, as a matter of fact, so far as the action of the latter is concerned, it is immaterial whether the throttle is used or not.

As a rule, the pilot valve used with the car lever controlling system is made with leather cup packings, so as to be perfectly water tight, but as will be seen in Fig. 12, the pilot valve used with this arrangement of magnet control is not provided with cup packings. This difference in construction is resorted to for the purpose of making the pilot valve move as freely as possible, so that it may be lifted or depressed by magnets of moderately small size. The pilot valve used in Fig. 12 is a solid plunger which is made an accurate free moving fit, by grinding the valve chamber barrel as well as the valve. The weight

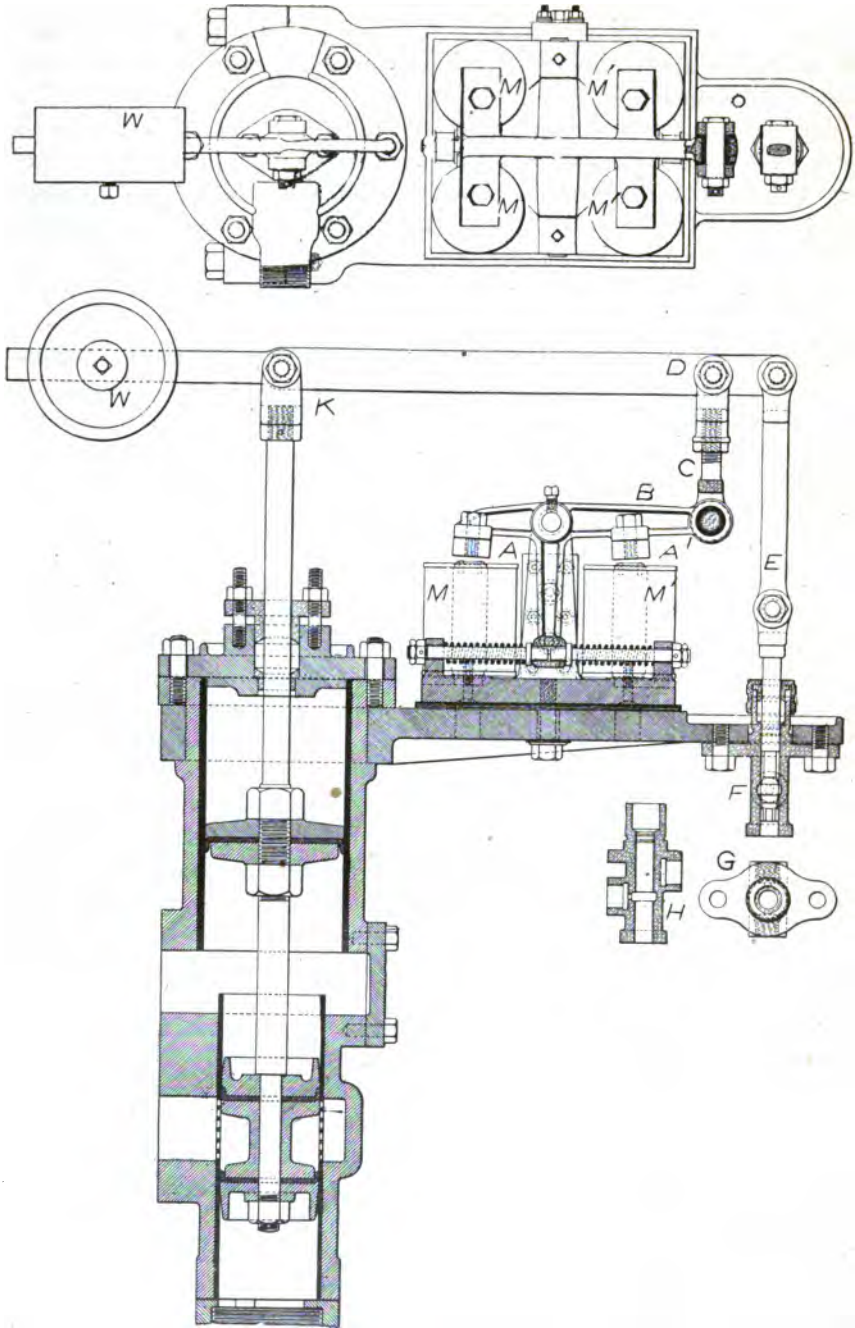


FIG. 12.

*W* placed on the end of the connecting lever *D* is for the purpose of counterbalancing the connecting rods *C* and *E*, the valve plunger, and the end of *D* to the right of the main valve rod, which latter acts as the fulcrum around which these parts rock when they are moved by the magnets *MM'*.

When the magnets *M* are energized, the iron armature *A* carried by the rocker arm *B* is pulled down, and thus connecting rod *C* is forced upward, and the pilot valve is lifted. If the magnets *M'* are energized, the iron armature *A'* is pulled down and then the pilot valve is depressed. Since the weight *W* balances all the parts of the valve connections to the right of *K*, the force to move the pilot valve is the same whether it is moved upward or downward.

The construction of the pilot valve chamber can be fully understood from the three views *F*, *G* and *H*, the first and the last being vertical sections at right angles to each other. In addition to making the pilot valve a solid plunger, it is arranged so as to have a shorter stroke than is used for the car lever system, so that the movement of the armatures *AA'* when drawn down by the magnets may be through as short a distance as possible. If the stroke of the valve were increased, the size of the magnets would have to be increased in greater proportion, because the pull exerted by magnets of this form falls off very rapidly as the distance of the armature from the poles of the magnet is increased.

As will be seen in the plan, Fig. 12, four magnet spools *MM* and *M'M'* form two separate horse shoe magnets, this form being used, as it gives a stronger pull for the same size and weight than a straight bar magnet. The armature *A* extends sidewise from the center so as to cover the tops of the iron cores of both the *MM* magnet spools. And in like manner *A'* covers the cores of *M'M'*.

Figures 13 and 14 show how the pilot valve and the main valve are connected. As will be seen in the first figure, the water coming from the supply pipe passes through a pair of strainers, which free it from chips or other particles that would be liable to clog the pilot valve. Two strainers are used simply for the purpose of making it possible to clean one while the elevator is in use.

Three-way cocks are provided at top and bottom of the strainers, and by turning these so as to send the water through one strainer, the other one can be taken apart and cleaned. In Fig. 14 the strainers are marked *SS*. The pipes are marked with the same letter in the three drawings, that is, *A*, for the connection between the top of the strainers and top of pilot valve barrel, and *B* for the connection between pilot valve and top of auxiliary valve chamber. The globe valve in pipe *B*,

when closed, prevents the water from entering or escaping from the upper end of the auxiliary valve chamber; hence, as long as it is closed, the main valve cannot be moved and the elevator will not run.

With the magnetic controlling device, the car can be operated from the various floors at which it stops, or from within the car, or from either position, all depending on how the connecting wires are arranged. The wiring diagram, Fig. 15, shows a simple arrangement of the wir-

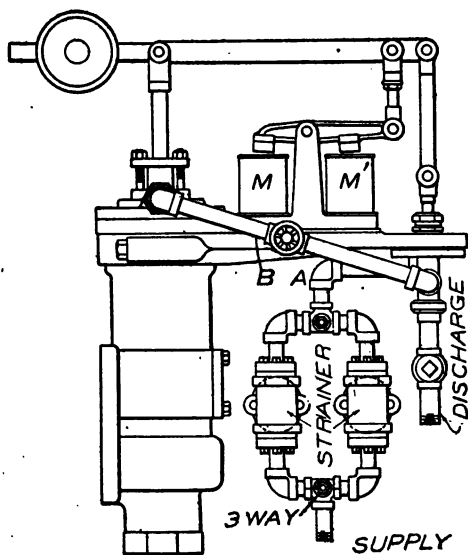


FIG. 13.

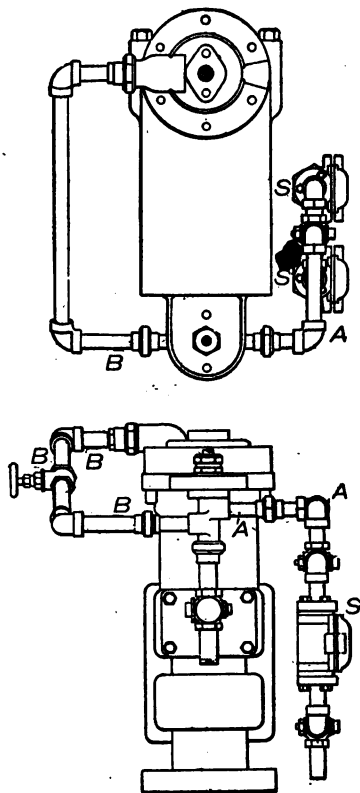


FIG. 14.

ing whereby the car can be operated from within or from any of the floors.

In this diagram, the wires *PN* are connected with an electric lighting circuit, and then, if the two-pole switch shown is closed, and the gaps below it are bridged with fuses as indicated, the current will traverse the various wires and pass through the magnet coils, so as to

run the car in either direction, if the floor switch is moved in the proper direction, or the proper car button is pushed.

If we start from wire *P* and pass through the right side of the two-pole switch and the corresponding fuse, we shall reach a wire that connects with the top binding post on the left of the binding post board. From here, the current will pass to wire *a* and following it will reach the junction with wire *n*. This latter wire, together with

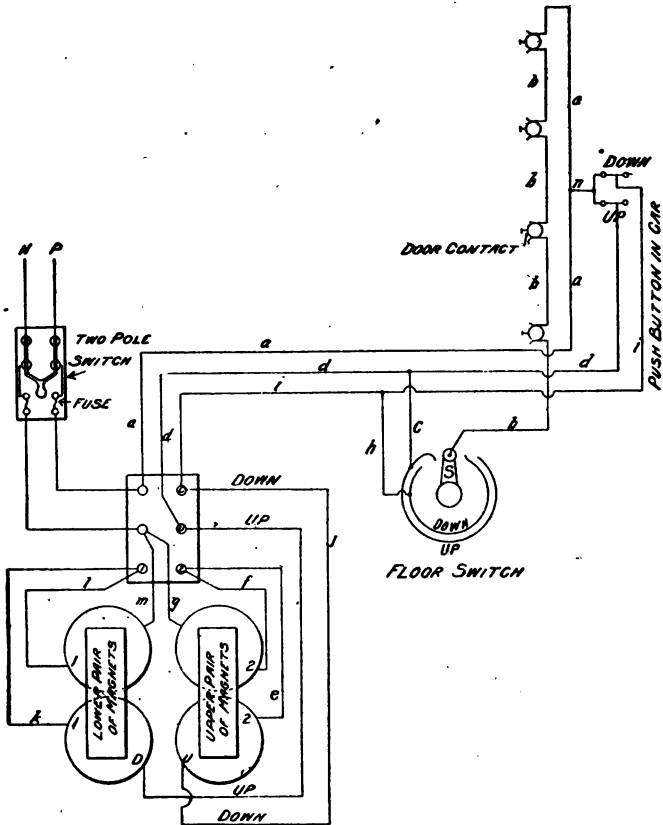


FIG. 15.

wires *d* and *i*, pass to the car through a long flexible cable that is attached to the elevator well half way up from the bottom. If the current follows wire *n*, it can go no further than the car, as the up and down push buttons are not in contact. If it follows wire *a* to the top of the diagram and then returns by wire *b*, it will reach lever *S* of the floor switch, but can go no further, as this switch is open. If, now, this floor switch is turned to the right, the current will pass to the

inner circle marked "down," and through wire *h* will reach wire *i* and thus the top binding post on the right. From here it will flow through wire *j* to the bottom right side magnet coil, and thence through wire *c* to binding post *z* and back through wire *f* to the upper magnet coil and then through wire *g* to the center binding post on the left side and thus back to line wire *N*.

If the floor switch is turned to the left, the current will pass to wire *d* and then through the two magnet coils on the left and finally out to line wire *N*.

The diagram shows only one floor switch, but there can be as many of them as may be desired, the lever *S* of all the switches being connected with wire *b*, all the *z* wires being connected with wire *d*, and all the *h* wires being connected with wire *i*.

If any one of the door switches in wire *b* is open, the car cannot be operated from the floor switch, for the current reaches the latter through wire *b*, and if the circuit in this is broken, the floor switch becomes inactive. This arrangement is made so that if the car is at a landing taking on passengers or freight, it cannot be set in motion by a person moving a switch on another floor.

Looking now at the car push buttons, it will be seen that, if the upper one is pushed, the current will pass to wire *i* and the car will run down, and if the lower one is depressed, the current will pass through wire *d* and the car will run up.

This diagram shows a very simple arrangement of the circuits, but it is open to the objection that if the car is running under the influence of the floor switch, it can be interfered with by moving the car push buttons; or if being operated from within the car, it can be interfered with by moving a floor switch. In more elaborate arrangements, which we will explain in a future chapter, the car cannot be interfered with, if set in motion from any floor or from within the car.

## CHAPTER IV.

BATTERY OPERATION OF MAGNETIC CONTROL AND AUTOMATIC PUSH  
BUTTON CONTROL.

**E**LECTRICALLY controlled hydraulic elevators, as explained in the last chapter, are arranged to be actuated by current derived from an incandescent lighting circuit. In many places such current is not available, and the only source of electric energy that can be used is a battery, either primary or secondary. Of these, the latter is the more economical, but both are decidedly more expensive than a current derived from electric lighting mains; hence, for operation with a battery current, the controlling apparatus must be made so as to require as small an amount of energy as possible. To attain this end a small hydraulic cylinder is provided to move the pilot valve, and the flow of water to this cylinder is controlled by valves that are much smaller than the pilot valve itself.

Of this type of valves, the general arrangement is clearly shown in Fig. 16, which is an elevation in section and a plan. The upper part, *U*, of the main valve and chamber is all that is shown, the lower part being cut away to reduce the size of the drawing.

In this design, the magnets are of the solenoid type; that is, they are provided with plungers *mm* that are drawn into the center openings of the spools *MM*. There are four magnet spools, *MM* and *M'M'*. The pair *MM* operates the valve rod *A* that runs into the valve chamber *B*. The pair *M'M'* operates a similar valve placed back of *B* in Fig. 16, the position of the two valves being shown at *B* and *B'* in the plan. One of these small valves controls the flow of water to the lower end of the hydraulic cylinder *D*, and the other valve in like manner controls the flow of water to the upper end *C*.

If water is admitted to the lower end, *D*, the piston and its rod, *E*, will be lifted; and if the water flows into the upper end, *C*, the piston will be depressed. When *E* is lifted, it raises lever, *P*, and, through connecting rod, *Q*, lifts the pilot valve, *R*. This movement opens the connection, through the pilot valve, between the upper end of the main valve cylinder and the discharge pipe, and thus the main valve is raised, which, as already explained, permits the water in the lower end of the lifting cylinder to escape and the piston to descend, lifting the elevator car.

Construction of the valve chamber, *B*, *B'*, is clearly shown in Figs. 17 to 19. The first figure is a vertical section through the

## BATTERY OPERATION.

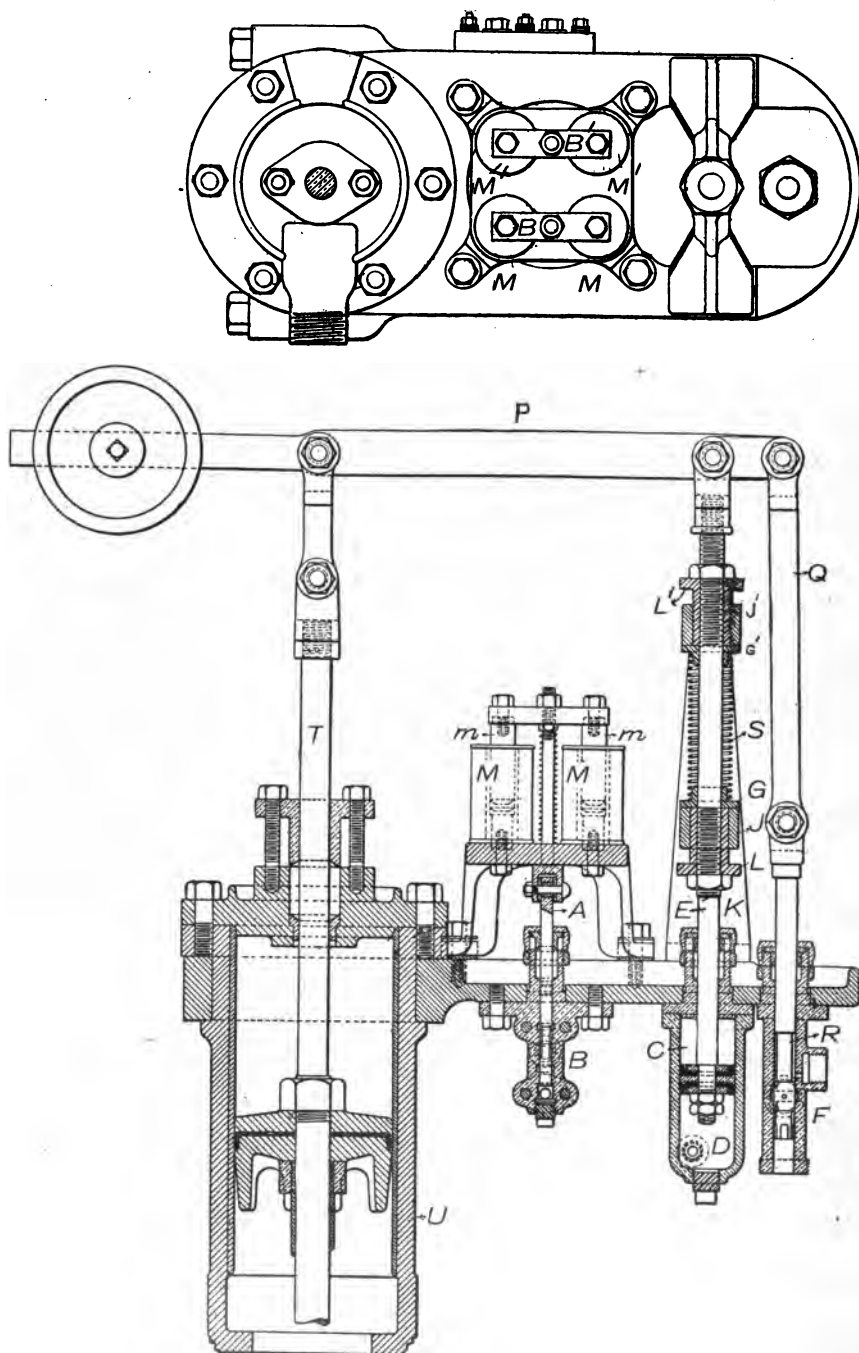


FIG. 16.

cylinders,  $B B'$ . As will be seen, the valve chamber consists of the two side parts,  $A$ , and the center,  $B''$ , the three being held together by bolts, as shown. Fig. 18 is a section through one of the sides,  $A$ . Fig. 19 is a section through  $B''$ .

It is apparent that the valves,  $B B'$ , can be much smaller than the pilot valve, and can be made to move with much less friction, because, if they do leak slightly, the only effect will be to keep both ends of cylinder,  $D$ , Fig. 16, full of water at all times, which is just what is desired, so that the movement of the piston may follow immediately upon the opening of either one of the valves.

Spring,  $S$ , presses against the caps,  $G G'$ , which in turn press against the bushings,  $L L$ , and keep the piston rod,  $E$ , in its central

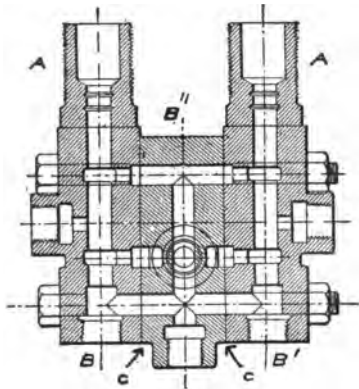


FIG. 17.

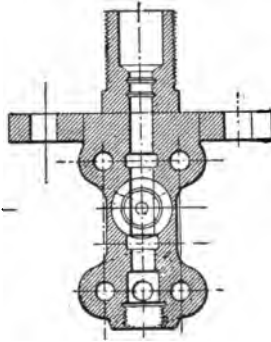


FIG. 18.

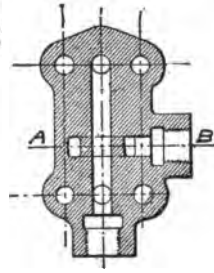


FIG. 19.

position, as  $G$  rests against the lower abutment bearing,  $J$ , and  $G'$  rests against the upper bearing,  $J'$ . Both these abutments are cast integral with the bracket,  $K$ . This design of magnetic controller can also be used with alternating currents, owing to the fact that the solenoid magnets will act with such currents, while the ordinary horse shoe magnet will not. For operation with alternating currents, the auxiliary hydraulic cylinder for actuating the pilot valve need not be used, but is, however, generally provided.

For this arrangement of valves, the piping system is shown in elevation and plan by Fig. 20. In both drawings, corresponding pipes are marked with the same letters, so that the system may be easily understood without an extended explanation. Fig. 21 is a photographic view of the whole valve gear, which will make still clearer the piping connections.

## BATTERY OPERATION.

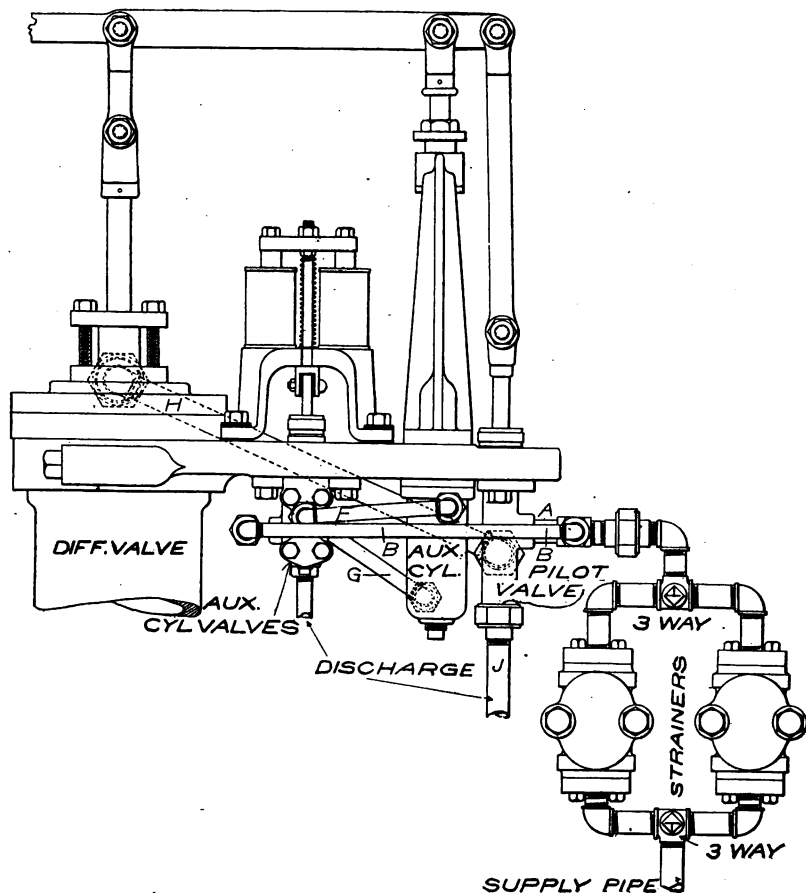
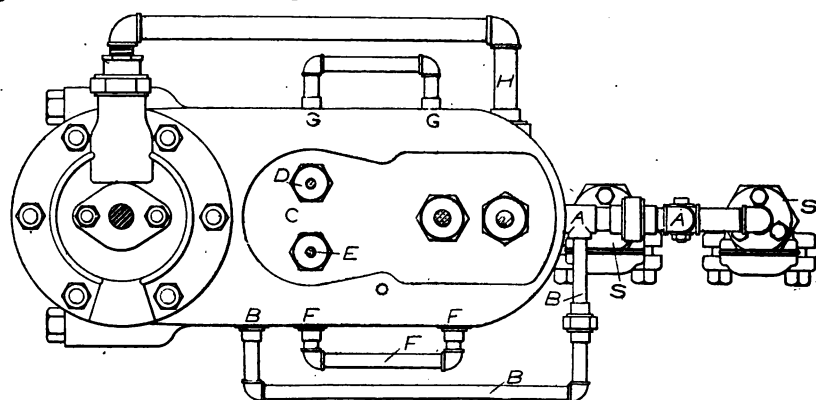


FIG. 20.

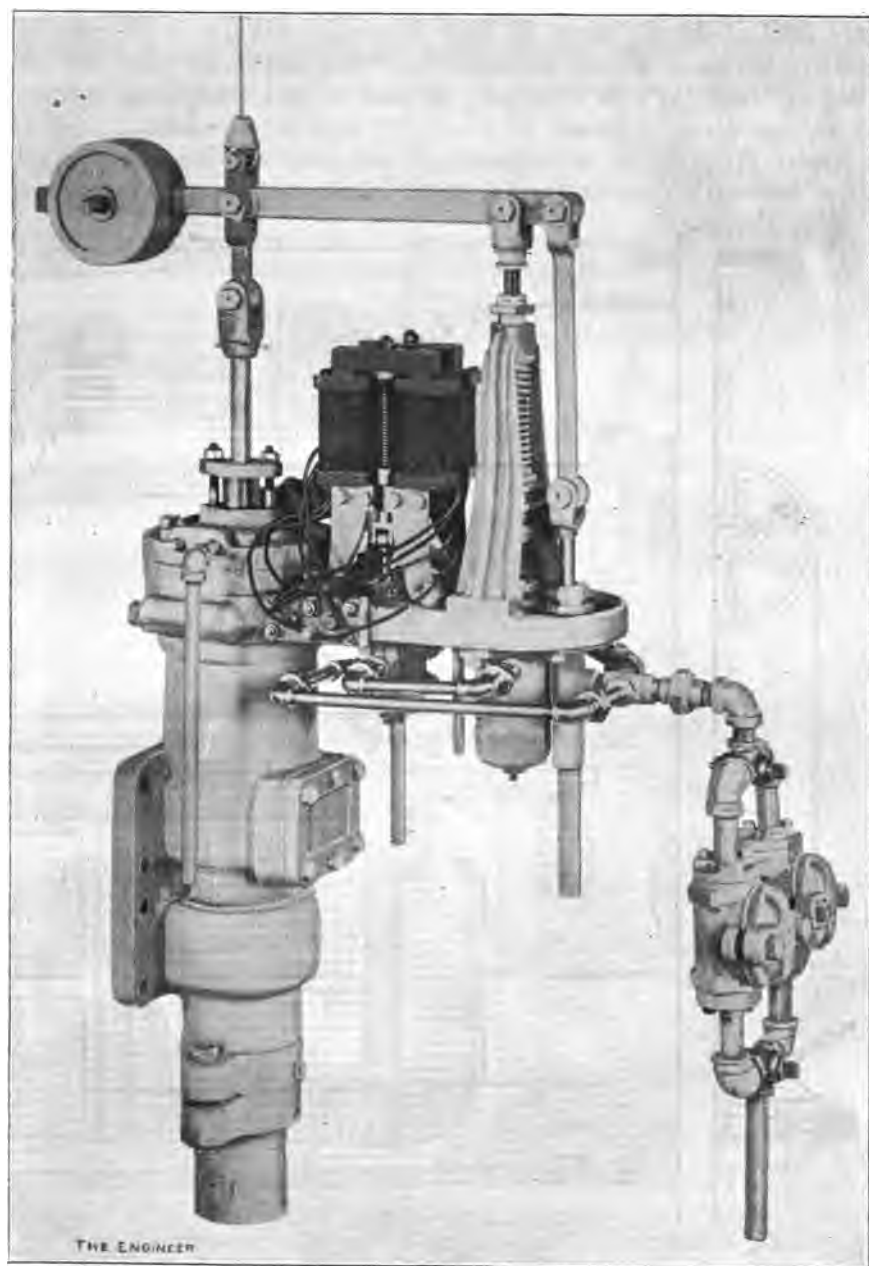
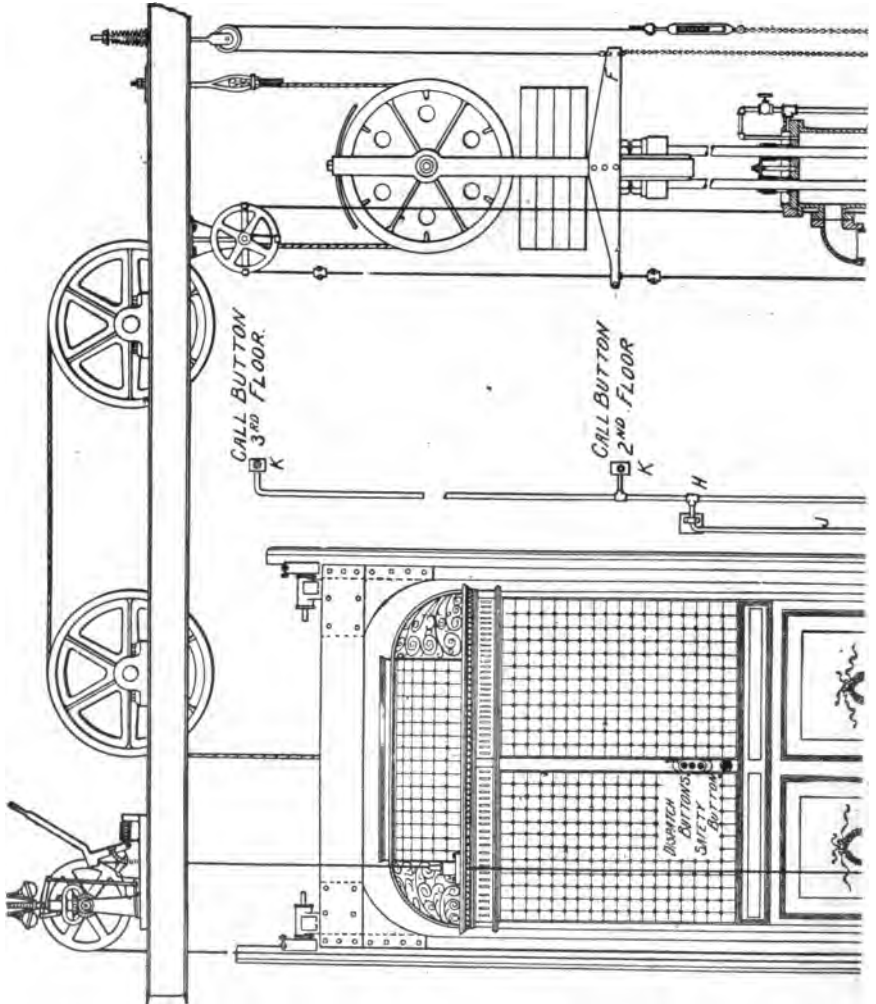


FIG. 21.

When elevators are placed in private houses, and also when they are used as dumb waiters in other buildings, they are, as a rule, arranged to be run without an operator. When such is the case, the controlling apparatus must necessarily be made so that when being operated from one place, it cannot be interfered with at any other place. In Chapter III, a simple arrangement of this kind was shown. We will now explain a complete arrangement which enables a person at any



floor to bring the car to that floor by simply pushing a button, and after entering the car to set it in motion and cause it to stop automatically at any floor by pushing the proper button in the car.

This type of controlling device is known as the automatic push button control. It is not difficult to see how a controlling system can be arranged so that by pressing one button the car is made to run up, and

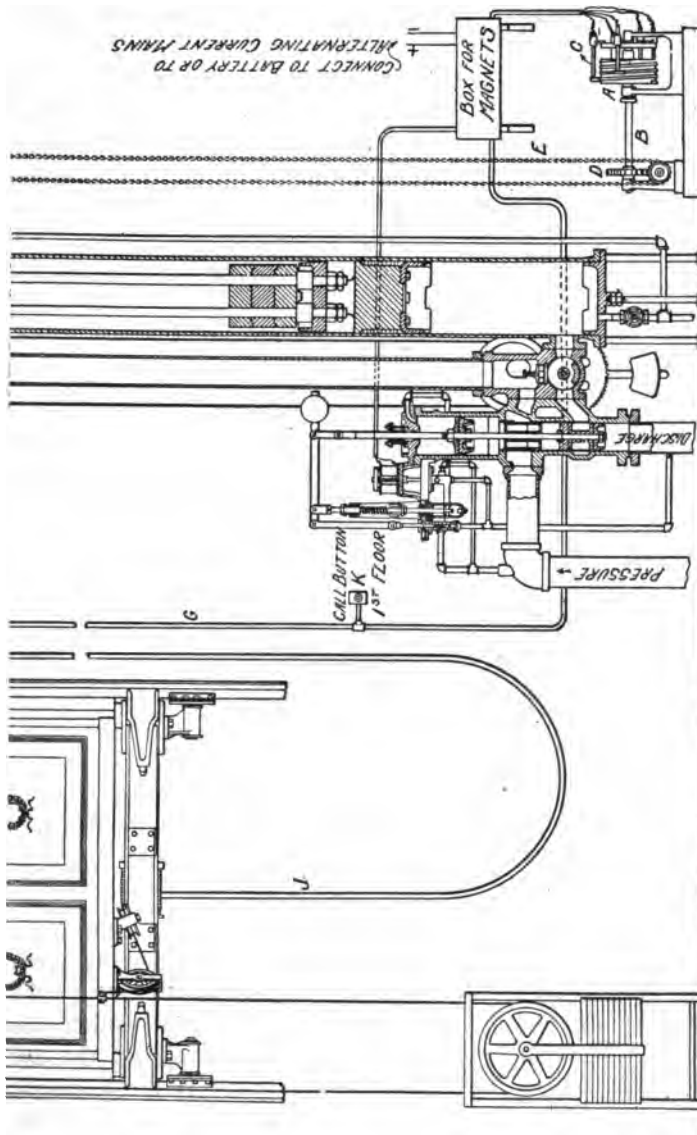


FIG. 22.

by pressing another button it is made to run down, but when the two operations are accomplished by the depression of the same button, the case becomes more complicated, especially when we consider that the

direction in which the car will move depends upon whether it is above or below the floor from which it is set in motion. If a man is at the third floor, for example, and pushes the button, the car will run down to that floor, if it is above, or will run up to it, if below, and when it reaches the third floor it will stop of its own accord.

How this result is accomplished can be understood from Figs. 22, 23 and 24, the first being a general drawing showing the car, the hydraulic cylinder and valves, and the controlling apparatus. The magnet box shown in this figure contains the magnetic switches which control the flow of current to the valve-actuating magnets, and also make and break the circuit connections so as to prevent any one from interfering with the movement of the car after it has been set in motion from any point.

At *A* is the apparatus for controlling the direction in which the car runs. The cable, *G*, carries the circuit wires to the several floors of the building, and also to the point *H* whence the cable, *J*, leads to the car. The wires running through the cables, *G* and *J*, pass through the magnet box, and terminate at the several brushes marked *C* on the apparatus, *A*, which latter is called a floor controller.

This controller, *A*, is a drum upon which is mounted a metallic strip wound spirally, like the thread of a screw, and cut in two at a point midway between the ends. The drum is mounted upon a shaft, *B*, which has a worm gear, *D*, secured to its end, which gear meshes into a screw, driven by the chain attached to the crosshead, *F*, of the hydraulic elevator cylinder. It will be seen that the movement of shaft, *B*, is in time with the movement of *F*, and, therefore, in time with the movement of the elevator car. The brushes, *C*, are set so as to rest on the strip wound upon the drum, and the shaft, *B*, is threaded at the end and passes through a nut secured to the frame which carries the brushes, *C*, so as to move these brushes endwise of the shaft at such speed as will keep them always upon the spiral strips.

One end of the metallic strip is connected with one of the main circuit wires, and the other end is connected with the opposite wire, so that if all the brushes, *C*, are on one side of the center gap in the spiral, the car will move in the same direction, no matter which one of the push buttons is depressed. This would be the case, if the car were at either the top or the bottom of the building. If the car is at some point between the top and bottom of the building, some of the brushes, *C*, will rest on one section of the metallic strip, and the others will rest on the other portion; hence, if a button that is connected with the right-hand half of the metallic strip is depressed, the car will

be set in motion in a direction opposite to that in which it would run, if the button were connected with the left-hand end.

In Fig. 23, the construction of the floor controller is more clearly shown, the gap which divides the metallic strip into two parts being plainly evident. Two of the brushes are resting on the strip below the break and one is above it. If either one of the buttons that are connected with the two brushes below the break is depressed, the car will be set in motion in a direction opposite to that in which it will run, if the button connected with the upper brush is depressed. If the



FIG. 23.

drum is rotated by movement of the car so as to run the break down below the middle brush, then, if the button connected with this brush is depressed, the motion of the car will be in the same direction as for the upper brush. From this it will be apparent that, when the brush connecting with any button is below the gap in the metallic strip, the direction of the car when the button is depressed will be the opposite to what it would be, if the brush were above the break.

By the aid of Fig. 24, which is a diagram of the wiring connections, the way in which the floor controller and other parts of the system act can be made clear. The battery switch serves the purpose of connecting either of the two batteries into the circuit. When this switch

is moved up or down, so as to close the battery circuit, the current will pass to the  $+$  wire, and thence to the car switch; and, through the small switch shown, it will reach wire,  $A$ , returning through the cable to wire,  $A$ , and following this to a point,  $a$ , just above the battery. The coils,  $a$   $b$ , represent a magnetic switch which is provided with two coils, one of which acts in opposition to the other.

If the current passes through both these coils, the switch contacts at  $c$  will not be separated, and the current will be able to pass to wire,  $B$ , which runs to all the floor push buttons, and also the car switch. If any one of the floor push buttons is depressed, the current from  $B$

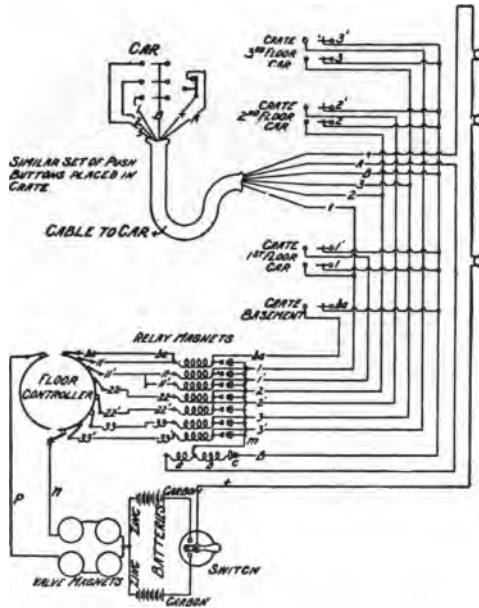


FIG. 24.

will pass through it to the corresponding wire of the sets marked from  $ba$  to  $3'$ . Suppose that  $ba$  in the basement is pressed; then the current will pass from  $B$  to  $ba$ , thence through the upper relay magnet to  $ba$  on the left, and to the top brush of the controller resting on the right-hand half of the contact strip. From here, evidently, the current will pass through wire  $n$  to and through the upper set of valve magnets.

As soon as the current passes through the relay magnet in wire,  $ba$ , the switch actuated by this magnet will be closed, and the current from wire,  $A$ , will pass through coil,  $a$ , of the lower magnet switch, to wire,  $m$ , and thence through the  $ba$  relay to wire,  $ba$ , and, as the current

will not pass through coil, *b*, of the lower switch, the contact at *c* will be opened and the circuit with *B* will be opened, so that no one can interfere with the running of the car by pushing any button, either on the landings or in the car.

With the floor controller in the position shown, if the car is at the bottom, the pressing of the basement button will not set it in motion, as the automatic stop will prevent the valves from being moved. If, however, the car is at the top of the building, it will run down and not stop until it reaches the basement. If the car is at some floor between the top and the bottom of the elevator well, the floor controller will not be in the position shown, but the gaps in the half circles that represent the metallic contact strip will be shifted around so that some of the brushes will rest on one half and the remainder on the other half. When the controller is in such a position, if the button pressed closes the circuit between *B* and a brush resting on the contact strip connected with wire, *p*, the direction in which the car will be set in motion will be the reverse of that obtained by pressing a button that closes the circuit between *B* and a brush connecting with wire, *n*.

Thus the floor controller makes it possible to set the elevator in motion in the required direction by the use of a single push button, and the relay magnets are for the purpose of breaking the circuit with all the buttons which are not in use, so that, when the elevator is set in motion from any point, it cannot be interfered with by any one at some other point. When the brush comes opposite the gap between the two halves of the connecting strip of the floor controller, the car is opposite a floor corresponding to that brush, and as the circuit is then broken at the floor controller, the car comes to a stop.

In this diagram, push buttons are shown for the car and the crate, it being arranged for a house elevator having a freight crate under the passenger car. If it is desired to bring the car even with the floor, the car button is pressed, and to bring the crate even with the floor, the crate button is pressed. The contact strips of the floor controller are shown as about one-half of a circle in the diagram, for the purpose of simplifying it, but in actual construction they are much longer, as shown in Fig. 23.

## CHAPTER V.

## DOUBLE-POWER ELEVATORS.

REGARDLESS of the load, a hydraulic elevator will use the same amount of water to run the car from the bottom to the top of the building; therefore, if the pressure remains the same, it will require just as much power to run with an empty car as with one fully loaded. If the pressure of the water used to operate the elevator could be varied in direct proportion to the load lifted, the power used could be made to vary in like proportion. This result can be accomplished by employing a pump to deliver water directly into the elevator cylinder, the pump being driven by a steam engine provided with a variable cutoff that is governed by the pressure due to the load, or by using a steam pump of a similar type.

As an ordinary automatic cutoff steam engine is governed by the speed, it will not meet the requirements. In elevator service the same load may sometimes be moved at double the velocity attained at other times; hence, the pressure at which the water is delivered must be independent of the speed. Arrangements to accomplish this result have been devised, and some that accomplish it fairly well have been put into use, but they are open to the serious objection that the pulsations of the pump can be felt in the car, which is permissible only in freight elevators.

As a rule, if the elevator is designed to lift a maximum load of, say, 2,000 pounds, the average load it will have to carry will not be over 800 or 900 pounds; hence, by arranging an elevator so as to be supplied with water at two pressures, one being about double the other, a great saving can be made in the power consumption, because on most of the trips the low pressure will be sufficient to give the car all the speed desired. Elevators arranged to be operated with two pressures are called double-power hydraulic elevators. One of this type, with vertical cylinder, as made by the Otis Elevator Company, is illustrated in Fig. 25. The cylinder and control valves are shown enlarged in Fig. 26.

To operate this type of elevator, two pumps are provided, pumping water into two separate pressure tanks. One set of operating valves is used and these are connected with the two tanks and with the discharge by means of suitable piping. The connection of these pipes is indicated in the illustration, the supply pipes being properly marked. The discharge pipe connects with the lower end of the valve chamber in the same manner as in single-pressure machines. A check valve is

provided in the low-pressure pipe to prevent the water from the high-pressure tank from running into the low-pressure tank.

When the operating lever, *R*, in the car, is moved to one side or the other, the cross beam, *U*, is likewise moved, in the manner fully explained in Chapter I. This movement raises one or the other of the side ropes, *TS*, and thus rotates the lower sheave and, through the connecting rope, the operating sheave, *C*, is rotated. If the valves are all in the position in which they are drawn, the car will be at a standstill, because the main valve, *H*, will close the outlet from the lower end of the hydraulic cylinder, thus preventing the escape of the water.

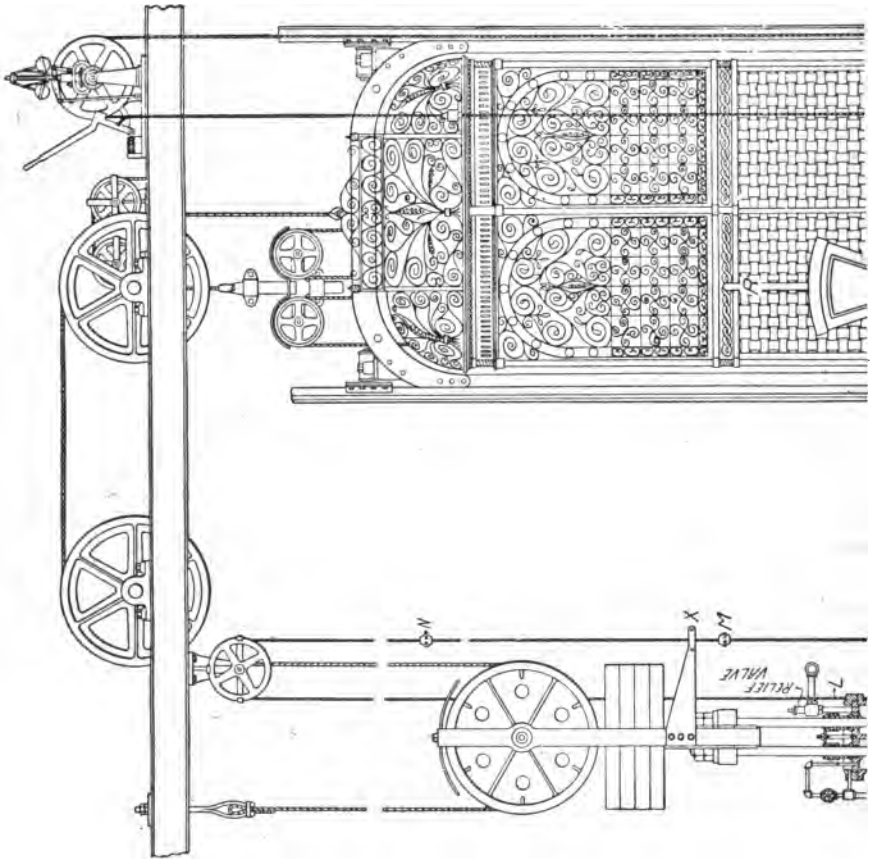
If the sheave, *C*, is turned counterclockwise, the rod, *D*, will raise the pilot valve and thus open communication between the upper end of the valve chamber and the discharge pipe, allowing the water above valve, *E*, to escape. This will permit the valve to rise, so that the water in the lower end of the elevator cylinder will be able to escape into the discharge pipe, while water from the low-pressure pipe will pass through the uncovered port holes below *G* and run into the upper end of the cylinder.

If the load is light, the operating lever, *R*, in the car, will be turned only a portion of its full movement, raising the pilot valve only a portion of its full stroke, and the main valve no more than a corresponding portion of its stroke. Under these conditions, the hydraulic cylinder will be filled with water from the low-pressure pipe only, because the lower end of valve *E* will remain below the port with which the high-pressure pipe is connected.

If the low-pressure water is not capable of moving the car, or of imparting to it the desired speed, the operator moves lever, *R*, further forward, rotating the sheave, *C*, to a more advanced position, and thus increasing the stroke of the pilot valve. This increase in the stroke of the pilot will result in lifting the valve, *E*, higher and thus uncovering a portion of the port holes connecting with the high-pressure pipe. Under these conditions, water will flow into the cylinder from the high-pressure pipe.

In considering the action of this system one would naturally suppose that as soon as the valve opens the ports connecting with the high-pressure pipe, the water coming therefrom would flow back into the low-pressure pipe and close the check valve, and that thereafter the elevator would be run by the high-pressure water exclusively. The actual operation of these elevators, however, shows that such is not the case, but that the check valve in the low-pressure pipe remains open, and that water is drawn from both tanks unless the load in the car is so great as to require nearly the full pressure of the high-pressure tank.

It certainly appears strange that water under a pressure of 100 pounds should run into the valve chamber from one pipe, when water under a pressure of 200 pounds is running in from another pipe. Several theories have been advanced to explain this action; the most plausible one being that the high-pressure water, in rushing through the valve chamber, produces an aspirator effect, and thus draws water in from the low-pressure pipe. Whether this theory is correct or not, it remains a fact



that water does flow into the elevator cylinder from the low-pressure tank, even when the pressure in the cylinder is 50 per cent higher than in the low-pressure tank.

In the single-pressure machine, as already explained, the valve at *J* permits water to be forced out of the lower end of the cylinder, if the operator closes the valve too rapidly when the car is going up, that is, when the piston is descending. When the car is running down, and the

piston is ascending, the water will simply back up into the supply pipe, if the valves are closed too rapidly. With this double-pressure system, this action cannot take place, because the check valve in the low-pressure pipe will prevent the water from flowing back into the low-pressure tank. Owing to this fact, it is necessary to provide a relief valve at the upper end of the hydraulic cylinder, as shown in the drawing.

In the double-pressure system, the automatic top and bottom stop-

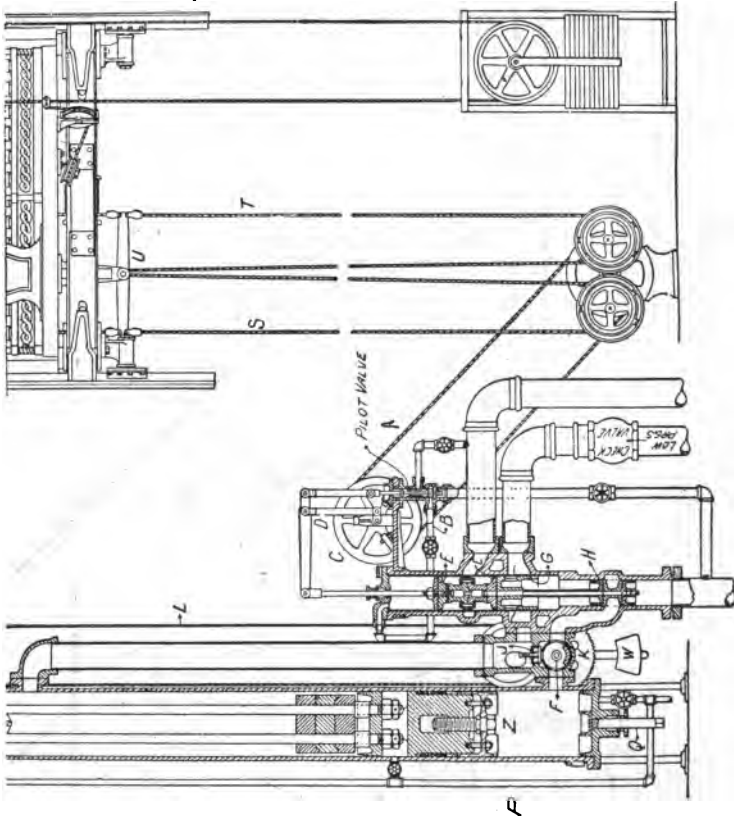


FIG. 25.

ping device is the same as in the single-pressure, the valve, *F*, being rotated by the movement of rope, *L*. A close inspection of the drawing will show that on the downward movement of the piston, cross-head, *X*, strikes the stop ball, *M*, and thus the lower sheave around which the rope passes is turned clockwise. As the gear, *K*, mounted on the end of the spindle of valve, *F*, is rotated by a pinion on the shaft of the rope sheave, its rotation will be counterclockwise; hence, when the

valve, *F*, is closed by this automatic action, the passage between the

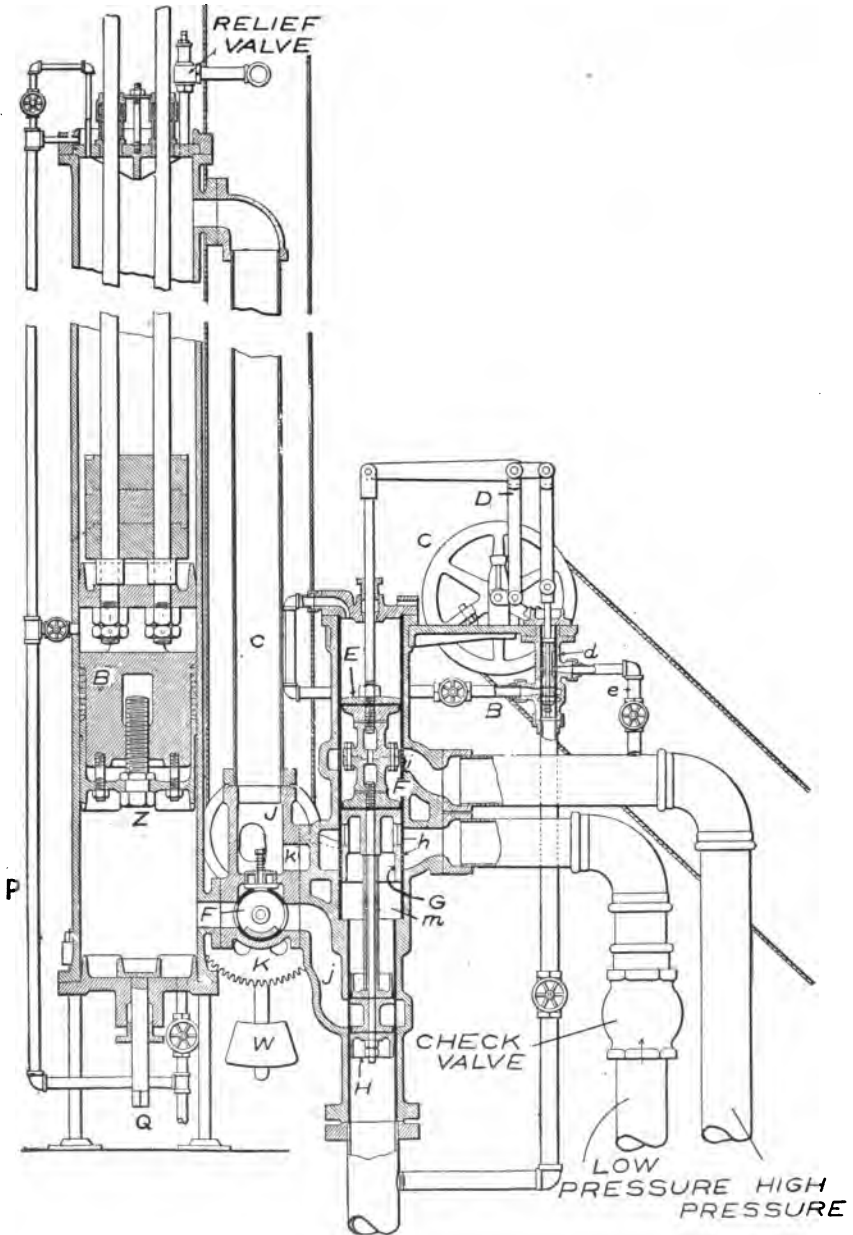


FIG. 26.

lower end of the hydraulic cylinder and the valve chamber is com-

pletely closed; but through the opening in the upper side of *F*, which will be turned toward the cylinder, a free communication is left with valve, *J*, so that, if, for any reason, the valve, *F*, is closed too rapidly, water can escape from the lower end of the cylinder through the relief valve *J*, the same as when the stop is effected by the movement of the pilot valve.

If the automatic stop comes into action on the up motion of the piston, gear, *K*, will be rotated clockwise, and in that case, if the stop is too sudden, the relief valve at the top of the cylinder will be opened.

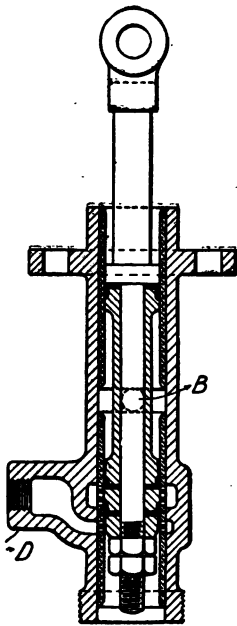


FIG. 27.

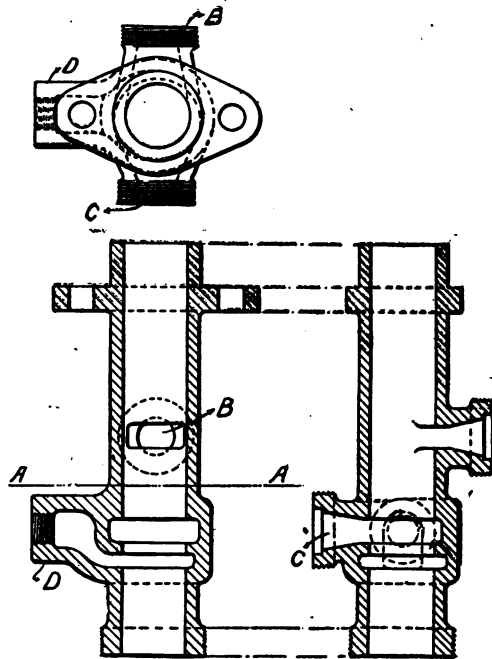


FIG. 28.

Thus it will be seen that even when the automatic stop device acts, the relief valves prevent a violent stoppage of the motion of the elevator.

Pipe, *P*, is for the purpose of drawing the water out of the cylinder whenever desired, but this is never done except to make repairs, or when the elevator is not in use.

Fig. 26 shows an arrangement which is sometimes used to provide an easy way of tightening up the piston packing without removing the cylinder head. The bar, *Q*, passing through the lower cylinder head, has a socket at its upper end that fits the bolt, *Z*, in the piston. By

tightening this bolt, the packing is compressed. This addition is not very often used, as it is considered preferable to remove the cylinder head when the piston packing is adjusted, so as to know positively whether it is being adjusted properly or not. The use of rod, *Q*, is a sort of blind process that leaves one in a state of uncertainty.

In the larger pilot valve drawings, Fig. 27 shows the valve and valve chamber assembled, the view being from the main valve side as seen in Fig. 25. Fig. 28 shows the valve chamber alone, the left-hand view being in the same position, with the top view above; and the right-hand view of the valve chamber in the same position as it is shown in Fig. 25.

Port, *D*, is provided for the attachment of a pressure regulator, which, at the present time, is not often used. In most cases this outlet is plugged up. This pressure regulator works as follows: The outlet, *D*, is connected with the upper end of the valve chamber, or with the pipe, *B*. There is a valve in this connection that is actuated by a pressure regulator, and this regulator is connected with the upper end of the hydraulic cylinder. If the load on the elevator is heavy, the pressure acting on the regulator will increase, and thus the valve in the pipe between the outlet, *D*, and the pipe, *B*, will be opened, and the water in the upper end of the valve chamber will escape and allow the valve, *E*, to rise so as to let high-pressure water into the cylinder. In practice, it has been found that this addition is not an improvement over the simpler arrangement.

## CHAPTER VI.

### HIGH-PRESSURE ELEVATORS.

**I**N large office buildings, the height to which the elevators run is such that the hydraulic cylinder must be excessively long, or else the gear ratio must be multiplied many times. Thus, if the building is 200 feet high, the hydraulic cylinder will have to be made with a stroke of 50 feet, if geared four to one, or of 25 feet, if geared eight to one. For vertical cylinders of the type used for low-pressure and for double-power systems, a stroke of much more than 30 feet is not desirable, as a vacuum will form under the piston when it reaches the top of the cylinder, unless a goose neck is provided in the discharge pipe, which is a complication to be avoided whenever possible.

Horizontal cylinders cannot be made so long as the vertical, since in almost every case there is a lack of space to accommodate them. In addition to the great height to which the elevators must ascend, the car speed demanded is generally the maximum that can be obtained with smooth and safe running. In consequence of the high car speed, and the height of the building, the hydraulic cylinders must be large in diameter as well as of great length.

It is usually desirable to reduce the size of the apparatus as much as possible, and in order to attain this end, high-pressure machines are commonly used in buildings of this class. Increasing the pressure under which the machines operate not only reduces the dimensions of the lifting cylinder, but it also reduces the size of the pipes connecting the cylinders with the pressure and discharge tanks, and these tanks with the pumps. Thus it will be seen that, by increasing the pressure, the total space occupied by the elevator machinery can be greatly reduced.

Types of hydraulic elevators previously explained operate at pressures that vary all the way from about 25 or 30 pounds per square inch up to about 200 pounds. The high-pressure machines, one type of which will be described here, are operated with pressures that range between about 700 and 1,000 pounds per square inch. Owing to this great increase in pressure, the operating valves have to be materially modified in design. Figs 29 to 32 illustrate the valve gear of the Otis high-pressure hydraulic elevator. Figs. 29 and 30 are elevations of the operating valves, the latter being in section and taken at right angles to the former. Fig. 31 is an elevation of the upper end of the valve chamber looking from the left of Fig. 29, or the rear of Fig. 30. Fig. 32 is a plan of the mechanism, looking downward upon the top of Fig. 29.

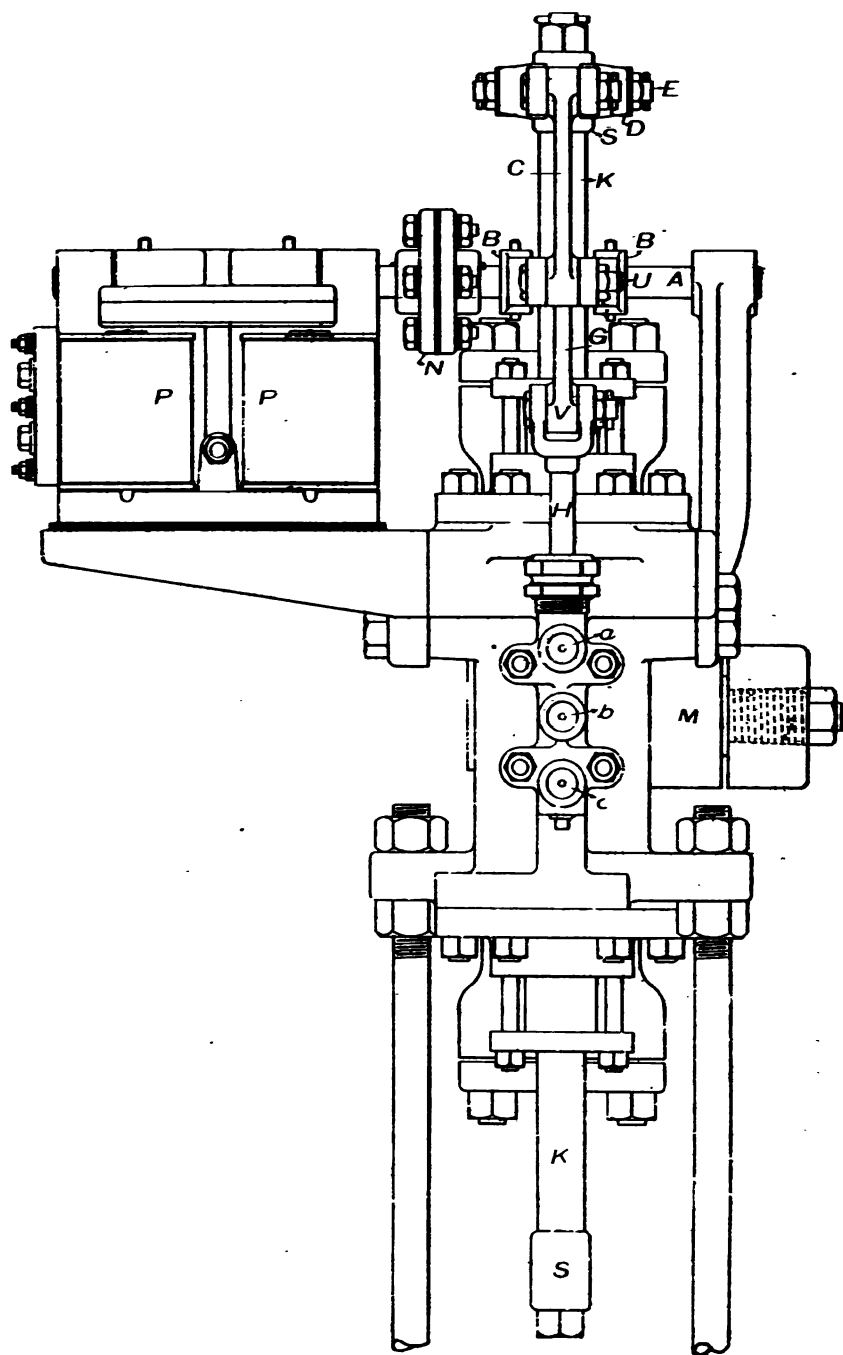


FIG. 29.

In these drawings, the pilot valve is actuated by magnets, but the same construction is used when a sheave wheel is employed. In Fig. 30, the shaft, *A*, is rotated by the magnets so as to swing lever, *B*, through a small angle either upward or downward, as the case may require. The disk, *N*, is a coupling which connects the shaft actuated by the magnets with the shaft that moves *B*, as can be clearly seen in Fig. 32.

Enlargements *d* and *e* on the lower end of rod, *H*, form the pilot valve, which controls the flow of water into the adjoining cylinder and thus moves the piston, *Q*. The rod, *K*, on which this piston is mounted, is connected by the crossheads, *SS*, with the main valve rod, *L*. It will be noticed that piston, *Q*, is much larger than the main valve rod, *L*, this latter being but a trifle larger than the rod, *H*, which forms the pilot valve. The reason for this difference is that while the main valve rod, *L*, controls the flow of water into the hydraulic cylinder under a pressure of, say, 1,000 pounds, the pilot valve, *H*, and the piston, *Q*, are subject to a pressure of only 30 or 40 pounds.

When the pressure is in the neighborhood of 1,000 pounds per square inch, a small leak will allow a large quantity of water to escape, and may thus permit the loss of a considerable amount of energy. This being the case, it is evident that, if the pilot valve were subjected to the full pressure, it would have to be made so as to be tight against such pressure, which means that it would not move as freely as is necessary to enable the magnets to actuate it, unless these were made of larger size than is permissible.

To obtain the low pressure to actuate piston, *Q*, the hydraulic cylinder discharges into a closed tank in which the pressure is maintained at a point somewhere between 25 and 75 pounds, which is found sufficient to move piston, *Q*. The supply pipe, *b*, of the pilot valve is connected with the discharge tank of the main hydraulic cylinder, and the discharge pipes of the pilot valve are connected with the waste pipe. The pump that keeps the main pressure tank supplied draws water at a pressure of, say, 40 pounds, and delivers it at 1,000 pounds, thus pumping against a net pressure of 960 pounds, so that there is no loss of power by maintaining a pressure in the discharge tank.

Operation of the valve is as follows: When shaft, *A*, is rotated so as to swing *B* upward, the connecting rod, *C*, carries *D* upward, swinging it around *E* as a center, thus depressing end, *F*, and weight, *W*. The upward movement of *D* lifts connecting rod, *G*, and pilot valve rod, *H*. In this way the valve, *e*, passes above the port, *g*, and allows water to escape from the lower end, *J*, of the cylinder in which piston, *Q*, moves. At the same time *d* is carried upward so that water from pipe, *b*, passes

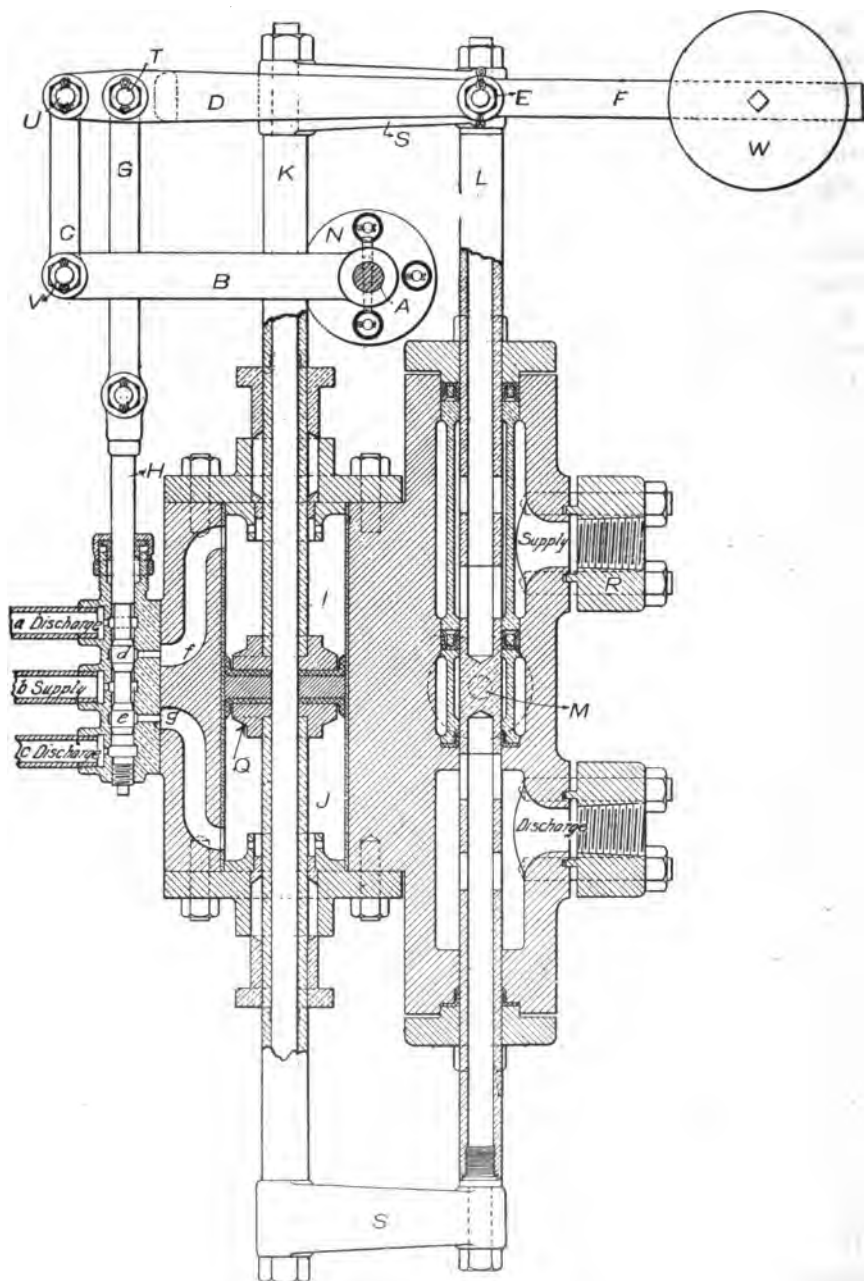


FIG. 30.

into space, *I*, above piston, *Q*. Thus it will be seen that the upward movement of *B* will cause *Q* to move downward, and as rods, *K* and *L*, are connected through crossheads, *S S*, the main valve rod, *L*, will move down together with *Q*.

This downward movement will bring the upper port holes in *L* opposite the opening, *M*, that connects with the hydraulic cylinder, and thus the high-pressure water from the supply pipe will pass into the hydraulic lifting cylinder. As the shaft, *A*, remains stationary while *Q* moves downward, the pin, *U*, acts as the center around which the levers

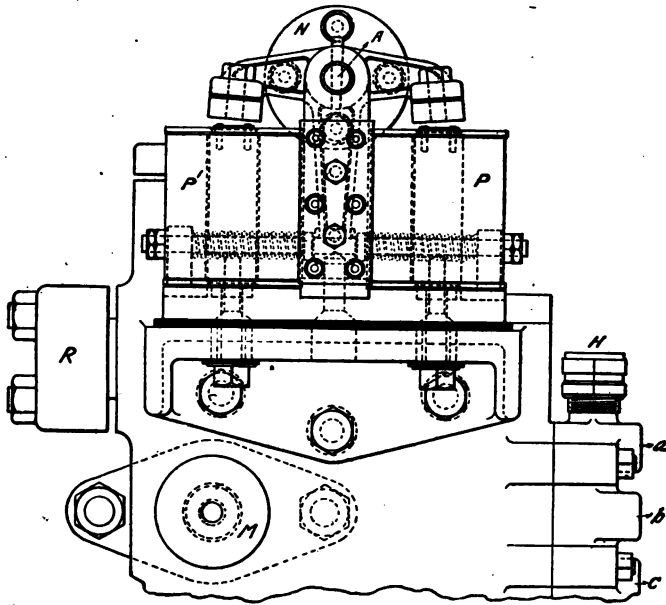


FIG. 3I.

swing, and thus the pilot valve rod, *H*, is carried down as well as rods, *K* and *L*, and, as a result, the pilot valve is returned to the closed position. If now shaft, *A*, is rotated further, the pilot valve will again be opened, and *Q* will be depressed still more, carrying *K* and *L* with it, and thereby opening the port holes in *L* still wider.

From this it will be seen that, if *B* is moved through a small distance by a correspondingly small rotation of *A*, the piston, *Q*, will be moved downward a short distance, and the ports in valve rod, *L*, will be only partially opened; but, if shaft, *A*, is rotated as far as it will move, then piston, *Q*, will be depressed through its entire stroke, and the ports in rod, *L*, will be opened to their full extent.

From the foregoing explanation it can be understood that to graduate the speed of the elevator car all that is necessary is to vary the distance through which shaft, *A*, is rotated.

When the valves are actuated by means of magnets, as in the illustrations here presented, this graduation cannot be obtained, because the magnets will move *A* to either one or the other of its extreme positions, or bring it to the center or stop position; hence, with the magnet control, the elevator can be run only at the full speed.

Several modified forms of magnetic controlling arrangements per-

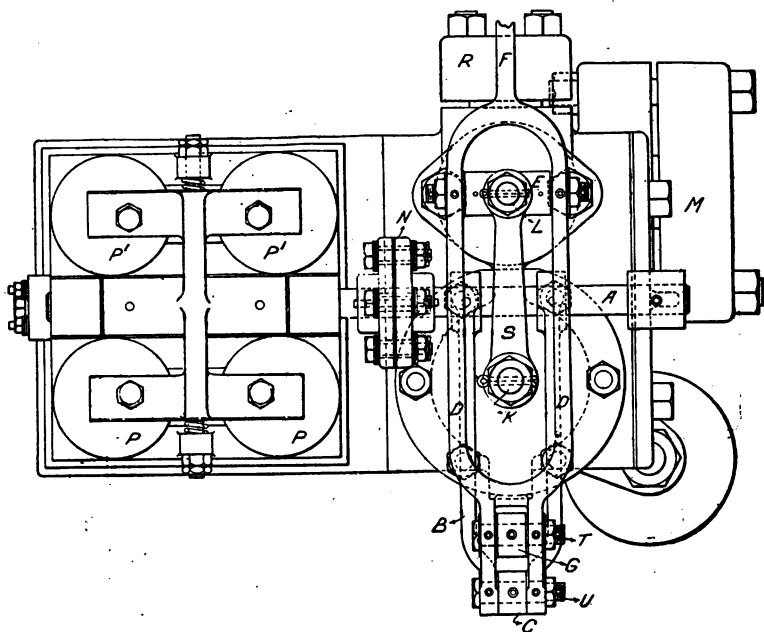


FIG. 32.

mit the shaft, *A*, to be moved through two or more different angles, thus obtaining two or more speeds, but these arrangements are more complicated than the magnets here shown and are not often used. The magnet control is only used in cases where it is unnecessary to vary the speed of the elevator, as, for example, where the elevator is for freight service, or is used as a dumb waiter. For first-class passenger service, where variable speed is necessary, the magnet control is replaced by a lever in the car which actuates a sheave mounted on the valve chamber, in a manner similar to that already explained in connection with low-pressure and double-power machines.

High-pressure elevators are made with a cylinder differing from

that used in low-pressure machines; that is, the cylinder is not provided with a piston and circulating pipe so as to allow the water to pass from the upper side of the piston to the under side and then to escape into the discharge pipe.

This construction would be inadvisable, because, owing to the high pressure, the diameter of the piston rod would have to be so nearly the same as that of the cylinder that the piston surface exposed would be very small. Furthermore, the difficulty of properly packing the piston would be great, and owing to the high pressure and the increased diameter of the piston occasioned by the presence of the piston rod, the power lost in friction would be great. For these several reasons the machines are constructed with a plunger that fills the entire cylinder, and the water presses against its end. In some cases the plunger is placed upright, and in others it is inverted; the latter arrangement is regarded as the more desirable, because with it the weight of the plunger can be utilized to counterbalance the elevator car.

Keeping in mind the fact that the hydraulic cylinder is of the plunger type, the operation of the main valve in Fig. 30 can be easily understood, for it can be seen that when  $L$  is raised, the flow from the supply pipe will be cut off, while the communication between the lifting cylinder and the discharge pipe will be opened so that the cylinder may be emptied. Thus the operation of valve,  $L$ , is first to connect the lifting cylinder with the supply pipe, so that it may be filled, and lift the elevator car, and then to connect the cylinder with the discharge pipe, so that it may be emptied and permit the car to run down.

## CHAPTER VII.

HIGH-PRESSURE ELEVATORS.—*Continued.*

**I**N Chapter VI we explained the type of valves used with high-pressure hydraulic elevators; we will now describe the elevator machine and the accumulator in which the water that operates the machine is stored. We will also show the kind of valve used when the elevator is operated by means of a running or standing rope with car lever.

In high-pressure machines, the cylinder with piston and piston rods shown in the low-pressure machines cannot be used advantageously, for the reasons given in Chapter VI. The most efficient design for high-pressure machines is the solid plunger type in which the plunger is forced out of the cylinder by the pressure of the water acting upon its end.

Some plunger machines are made so as to force the plunger out of the upper end of the cylinder, in which case they are called upright machines, and others so as to force the plunger out of the lower end of the cylinder, in which case they are called inverted machines. The inverted plunger is more desirable on the score of safety, for it must weigh less than enough to counterbalance the elevator car; hence, if the packing leaks or the water escapes from the cylinder in any other way, the car will gradually settle until it reaches the bottom of the well, or, if it is already in this position, it will stay there.

With the upright machine, the plunger must weigh enough to overbalance the elevator car when loaded to its fullest capacity, so that when the water is removed from the cylinder, the plunger will descend and thus lift the car. This being the case, it is clear that, if the cylinder springs a leak, the escape of the water will permit the plunger to descend and thus cause the car to ascend, and, if the water escapes from the cylinder fast enough, the car may be shot up to the top of the building at a dangerous velocity.

This would be the result if the cylinder should crack and let out all the water at once; but with the inverted machine the result in such an event would be that the car would descend to the bottom of the well, and if its speed became excessive, it would be caught by the safety devices provided for such emergencies.

Inverted plunger machines are made so as to be geared two, four or more to one. In Fig. 33 is shown a machine that is geared four to one. Fig. 34 shows two views at right angles to each other, of the cylinder,

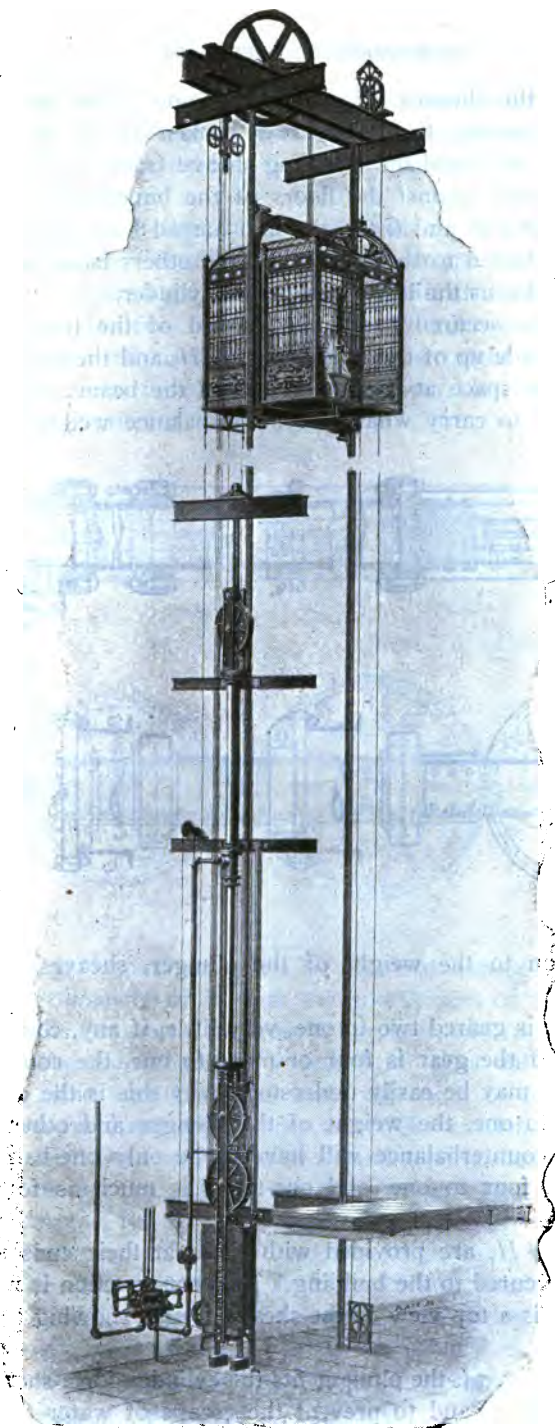
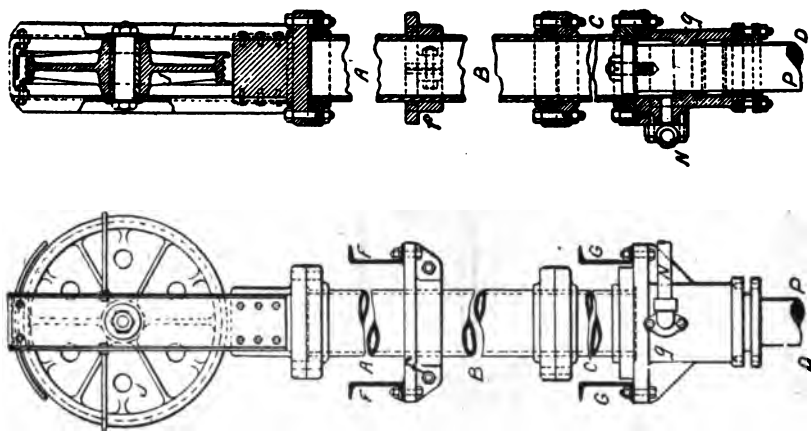


FIG. 33.

the plunger and the sheaves, of such a machine. For the purpose of shortening the drawing, the cylinder is broken at *A*, *B* and *C*, the plunger is broken at *D* and the traveling sheave frame at *E*. The cylinder is secured firmly against the floors of the building by strong iron beams as shown at *FF* and *GG*; the first named being near the top of the cylinder, and bolted to the casting, *f*; the others being bolted to the casting, *g*, which forms the lower end of the cylinder.

Plunger, *P*, is secured to the upper end of the traveling sheave frame, which is made up of the crossheads, *HH*, and the connecting side beams, *KK*. The space at the lower end of the beams, *KK*, from *L* to *M*, is provided to carry whatever counterbalance weight may be re-



quired in addition to the weight of the plunger, sheaves and sheave frame.

If a machine is geared two to one, very little, if any, counterbalance is required, but, if the gear is four or more to one, the counterbalance may be large. It may be easily understood why this is the case, for, if the gear is two to one, the weight of the plunger and other parts together with the counterbalance will have to be only one-half as great as for a gear of four to one, and one-third as much as for a six to one gear.

Crossheads, *HH*, are provided with shoes at their ends to run on guides properly secured to the building. This construction is well shown in Fig. 35, which is a top view of the sheave frame, showing the stationary guides at *aa*.

As shown in Fig. 34, the plunger fits the cylinder for a short distance at the lower end only, and to prevent the escape of water the cylinder

terminates in a stuffing box. By using this construction, the upper part of the cylinder may be made an inch or two larger than the plunger and strong wrought iron pipe may be used, thus greatly increasing the strength of the structure.

Short plungers are sometimes made with the cylinders bored true throughout their entire length, and the plungers are provided with regular hydraulic cup packings at the ends. This arrangement is not so good for long cylinders, as with it the cylinder must be made of cast iron, which not only is much weaker than wrought iron to withstand a bursting strain, but, in addition, cannot always be relied upon to be free from flaws or other defects.

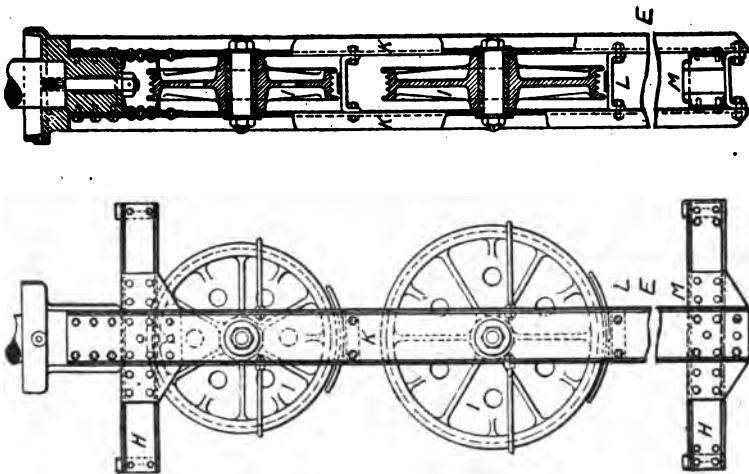


FIG. 34.

For operating the plunger, water is admitted through the pipe, *N*, this pipe being connected at *M* with the middle port of the valve shown in Fig. 30. If the elevator is for freight purposes, and runs at a moderate velocity, the elaborate valve gear required for pilot valve operations is not necessary, as in such cases the main valve can be operated directly by pulling upon the hand rope in the car. The external appearance of one design of valve for operation with a hand rope is shown in Fig. 36.

In this drawing the pipe, *N*, of the plunger cylinder is connected with the middle pipe, the two side pipes being connected with the supply and discharge as indicated. The hand rope that passes through the car is shown at *BB*, and the sheave around which it passes is marked *A*. The rack upon rod, *C*, meshes with a pinion on the sheave shaft as shown. The endwise movement of rod, *C*, shifts the valve rod, *D*, and thus the flow of water to or from the plunger cylinder is controlled.

Fig. 37 shows a hand rope operating valve, of a slightly different

design. The pipe from the plunger cylinder is connected with the center port, *A*. The valve rod, *C*, is moved by a connection from its end, *B*, to the rack rod, *C*, of Fig. 36. By comparing Fig. 37 with the pilot valve gear shown in Fig. 30, it will be seen that it is precisely the same as the main valve in that gear; the additional parts of the latter are provided solely for the purpose of reducing the effort required to move the valves so that they may be readily operated by turning a wheel or

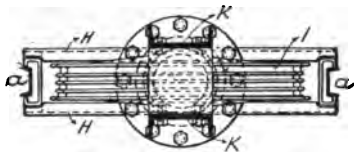


FIG. 35.

throwing a lever in the car through a small angular distance. When a simple hand rope is used, the rod, *C*, is moved a short distance endwise, while a sheave is rotated through a large portion of a revolution, and the hand rope in the car is pulled through a distance of from 3 to 6 feet.

For high-pressure work, the pressure tanks used with low-pressure elevator machines cannot be advantageously employed, owing to the fact that with such tanks, the pump must handle air as well as water, and it

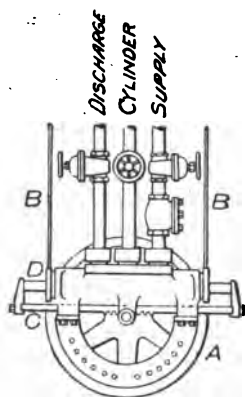


FIG. 36.

is difficult to pump air against a pressure of 800 or 1,000 pounds to the square inch. In ordinary pressure tanks, about one-third of the tank is filled with air, which expands as the water is withdrawn, and thus acts to keep the pressure nearly uniform.

If the tank were filled completely with water, the pressure would drop to nothing upon the removal of a very small quantity, as water

is practically incompressible. Air, however, is highly compressible so that, if a large portion of the tank is filled with it, all the water can be drawn out without effecting a great reduction in the pressure. The air in the pressure tank gradually escapes, either through leaks or by passing out with the water; therefore, to keep up the proper amount of air in the tank, it is necessary to pump some in occasionally.

With high pressures this is an objection, because, if we undertake to pump air against a pressure of, say, 800 pounds, the air drawn into the pump cylinder must be compressed until it reaches a pressure of 800

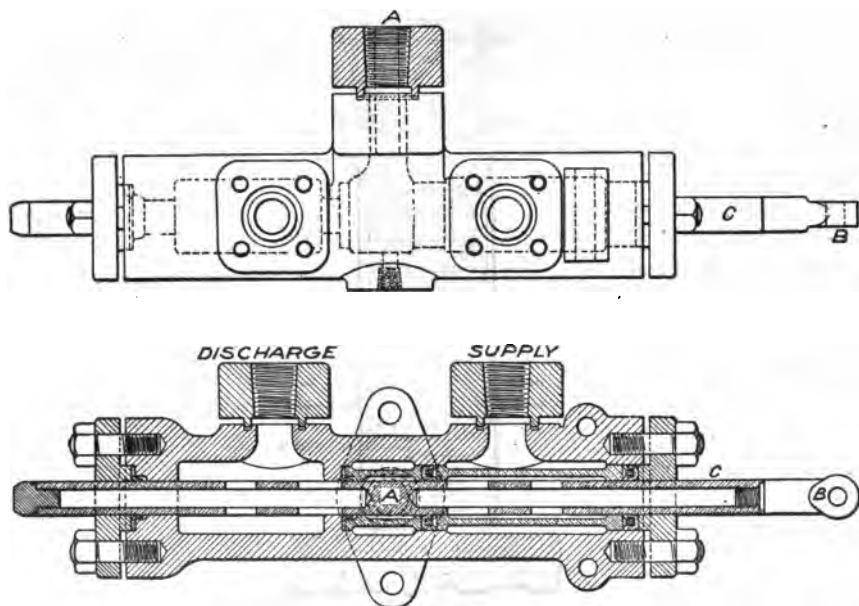


FIG. 37.

pounds before the discharge valves will open and allow it to pass into the tank. Practically, this would mean that, if we had a pump with a stroke of about 13 inches, the piston would travel to within about  $\frac{1}{4}$  inch of the end of its stroke before any air would be forced out of the cylinder. If the clearance at the end of the stroke were 1-16 inch, only three-fourths of the air drawn in would be forced out into the pressure tank. Generally, when air is pumped against very high pressures, it is done in two operations, one pump charging a tank, at, say, 100 pounds, and a second pump drawing air from this tank and forcing it against 1,000 pounds into another tank.

In elevator work, with high pressure, to avoid the complication of

additional pumps, the pressure tank is replaced by an accumulator. An accumulator is simply a hydraulic cylinder provided with a plunger which is loaded with as much weight as may be required to develop the pressure desired in the cylinder. One design of accumulator used in elevator work is shown in Fig. 38.

Water enters and passes out of the cylinder through a pipe at *A*. The plunger passes through an opening in the weights above it and abuts against the under side of the top crosshead. The bolts, *D*, pass down to the lower crosshead, and thus the weights are supported. The opening through the weights, which is indicated by the broken lines *a a*, is just

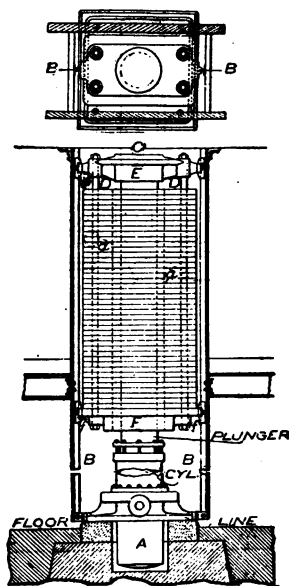


FIG. 38.

large enough to clear the cylinder, the latter being contracted as much as possible so as to reduce the diameter of the hole through the weights. The accumulator is shown in the position it reaches when fully charged; when it is empty the weights drop down as the plunger descends and completely encase the cylinder.

Where there is an abundance of head room, the weights are made solid and carried on top of the plunger. In such cases the space between the top of the upper crosshead and the ceiling, marked *C*, must be equal to the stroke of the plunger.

One advantage of an accumulator over the pressure tank is that the pressure remains unchanged at all times, because it depends upon the weight resting upon the plunger, and not upon the amount of water.

The lower end of the plunger is made with a flange that strikes against a corresponding flange projecting inward at the upper end of the cylinder, so as to avoid the accidental forcing of the plunger entirely out of the cylinder. In addition to this, automatic means are provided to stop the pump when the accumulator is full, and to set it in motion as soon as water is withdrawn and the plunger begins to run down. The crossheads, *E* and *F*, are provided with shoes, *ee* and *ff*, that run on the guides, *BB*, so as to keep the plunger in line.

Diameter and stroke of the accumulator cylinder are made such that the quantity of water it will hold is a little more than sufficient to fill the elevator cylinder. From this fact it will be seen that the pump must be large enough to supply water to the accumulator nearly as fast as it is withdrawn by the elevator when the latter is in action. In large buildings, where the elevators are constantly running, this is not an objection, as even with pressure tanks the size of the pump cannot be materially reduced; but in small buildings, where the elevators do not run all the time, the size of the pump may be greatly reduced by providing a tank that will hold enough water to make several trips, for while the elevator is not running, the pump can fill up the tank. For such service, therefore, the regular pressure tank with low-pressure elevator machines is the more desirable. The proper field for high-pressure machines actuated by means of accumulators, is in large office buildings where space is valuable and the elevators are constantly in service.

## CHAPTER VIII.

## ELEVATORS FOR PASSENGER SERVICE.

**I**N CHAPTER VI, we described the type of high-pressure valve used in connection with an electromagnetic controlling device. Valves of this kind are provided with what are called "automatic elevators," under which name are included dumb waiters, private house elevators and private elevators in other buildings, operated by pressing a button either in the car or at the landing, as described in Chapter IV. For this type of elevator, an attendant is not required, the person using the car acting as operator. In large office buildings and hotels, where elevator operators are provided, the controlling valve is arranged to be moved by means of a lever in the car, the motion of this lever being transmitted to the valve through rope connections of the nature already explained.

This type of control is far more desirable when an operator runs the car, than the magnetic device, because it gives the operator more perfect control of the movement of the car. With the magnetic arrangement, all that can be done is to set the car in motion and when it reaches the proper floor it will stop; but with the lever control, the car can be started from any position in the elevator well and be stopped at any other desired point. In addition, the speed while running can be varied to any extent desired, and, in starting or stopping, the motion can be accelerated or retarded as rapidly or slowly as may be necessary. . .

In this chapter we shall describe the type of valve used with lever control for first-class passenger elevators. We shall also describe the several auxiliary devices which are used for safety, and to secure certainty of action and smoothness of motion of the elevator car.

Fig. 39 shows the design of main and pilot valves used with car lever control. The general design is substantially the same as that of the magnetically controlled valve, although a careful examination will show that there is a considerable difference in the smaller details. The operating lever, which is connected with the car lever through the rope gear already referred to, is located upon the end of shaft, *A*. The movement of this shaft rocks lever, *B*, thus moving connecting rod, *C*, and, thereby, lever, *D*, and connecting rod, *E*, which connects with the pilot valve rod. The lever on the end of shaft, *A*, therefore, simply replaces the magnets of the magnetically operated valve, and imparts motion to the pilot valve in precisely the same manner. As the action of this valve was fully explained in connection with the magnetically

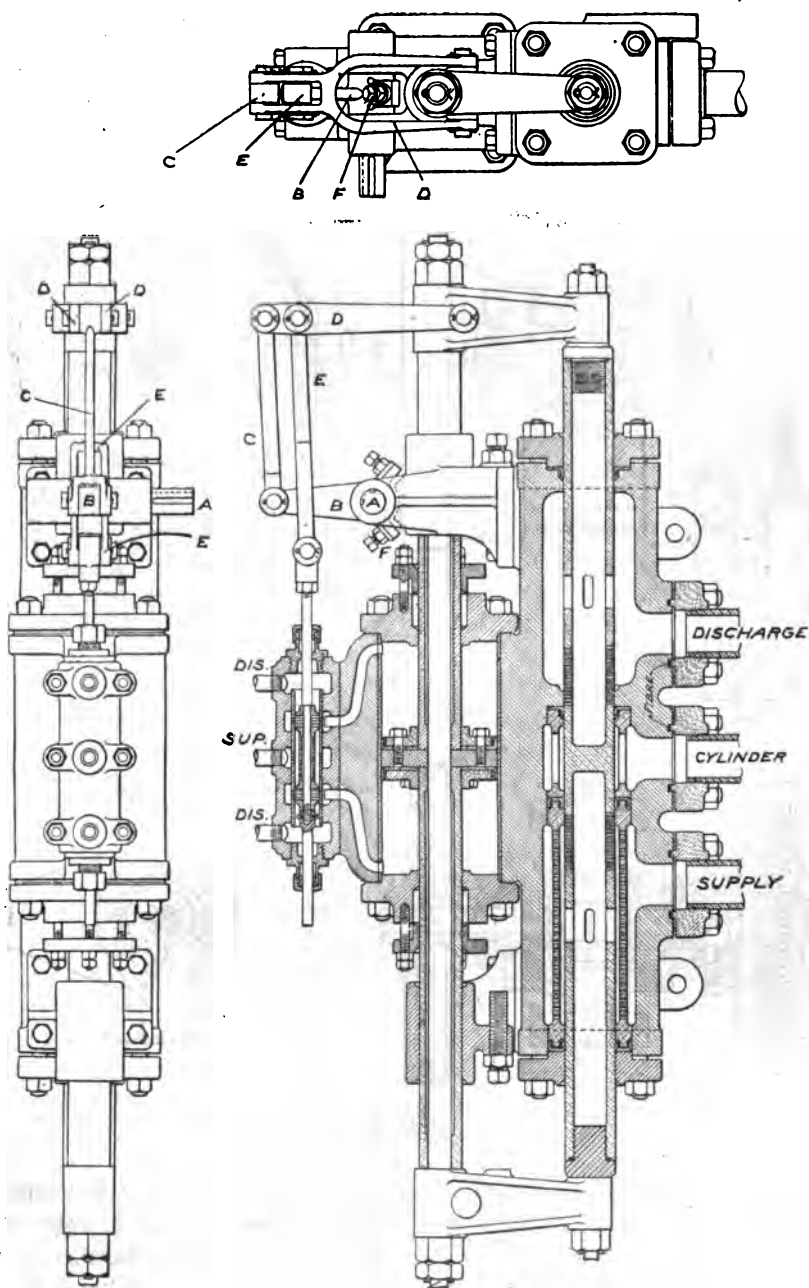


FIG. 39.

operated valve, it is not necessary to consider it further in this connection.

Fig. 40 illustrates the type of valve used with high-pressure elevators to stop the car automatically at the top and bottom landings. This valve is placed close to the hydraulic lifting cylinder, and the sprocket

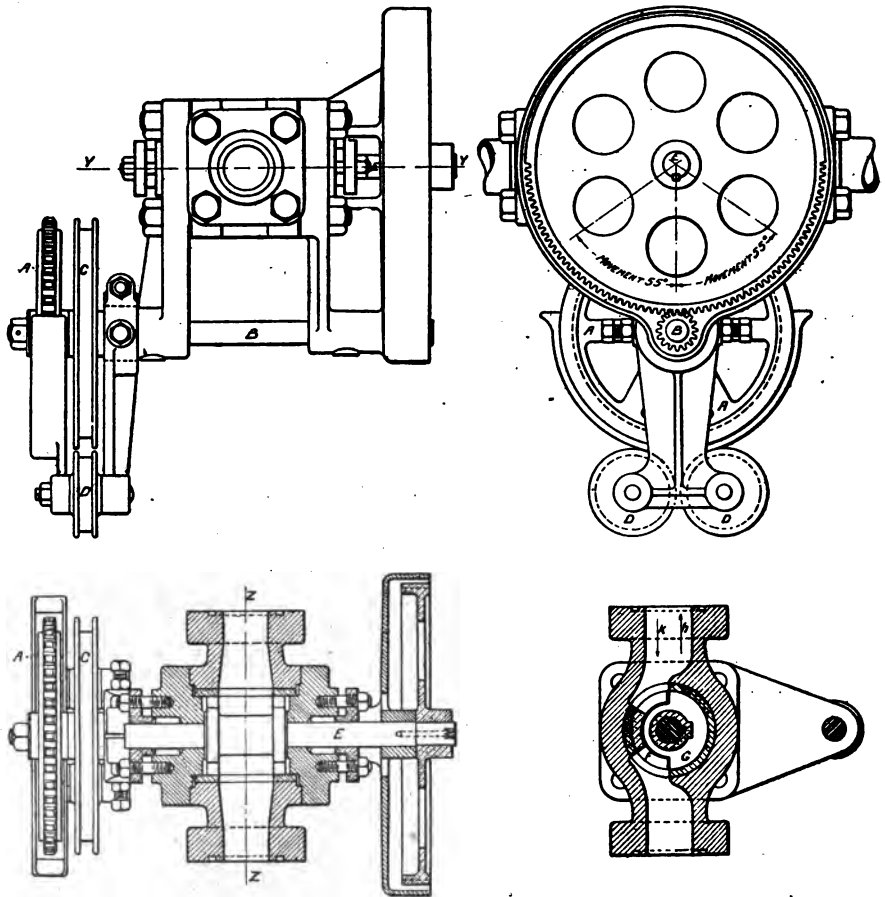


FIG. 40.

wheel, *A*, is rotated by means of a chain that passes over it and under a similar wheel located at the proper distance below it in the elevator well. The two wheels are so placed that the chain may run parallel to the traveling sheave over which the car lifting ropes pass. Stop balls are mounted on the chain in such positions that they are struck by an arm

projecting from the traveling sheave frame, when the car is at the proper distance from the top and bottom landings.

When the arm strikes the stop ball, sheave, *A*, is rotated, and thus the valve is moved so as to stop the flow of water in or out of the lifting cylinder, as the case may require, and thus stop the elevator car. As will be seen, the shaft, *B*, upon which *A* is mounted, carries a pinion that meshes into a gear on the valve shaft, *E*, so that *A* can rotate through several revolutions before the valve, *F*, is shifted far enough around to completely close the port. The wheel, *C*, is for the purpose of returning the valve to the central position; a strap attached to this wheel, *C*, passes between the small wheels, *D D*, and carries at its end a weight sufficient to rotate shaft, *B*, whenever it is free to move.

This gearing up of the movement of *A* is to produce a gradual closing of valve, *F*, and thus stop the elevator car without a jar. The valve, *F*, does not fit tightly in *G*; hence, if the valve is moved downward to stop the car, as would be the case, if the flow of water is in the direction of arrow, *k*, the pressure would hold it tightly against the seat, but, as soon as the main valve is reversed and the flow of water changes to the direction of arrow, *h*, valve, *F*, will be forced away from its seat and sufficient water will pass through to start the elevator at a low velocity. The instant the elevator begins to move, the arm that struck the stop ball and rotated valve, *F*, will move and allow the weight attached to *C* to rotate the latter and gradually return *F* to the open position, imparting to the elevator car a gradually increasing speed.

First-class passenger elevators in modern office buildings run at high velocities, the speed seldom being less than 400 feet per minute and frequently as high as 600 feet. With such high velocities, it is evidently desirable to provide some kind of speed governor that is positive in its action. If the lifting capacity of the hydraulic cylinder is such that it can impart the maximum speed to a heavily loaded car, with one or two passengers the velocity could be dangerously high, if the main valve were opened wide. To prevent the car from attaining too great a speed, the operator opens the valve only as much as may be required to give the proper amount. This arrangement, however, is not advisable, because it is possible for the operator to become confused, and, if he should, the results might be serious. To render the operation of an elevator as safe as possible, it is necessary to provide a speed governing device that will not permit the car to attain a dangerous velocity.

In connection with the Otis high-pressure system the speed regulator shown in Fig. 41 is used. This device will not permit the car to attain an excessive speed under any conditions, simply because it depends for its action upon the velocity of the current of water passing through

it and not upon the pressure. The device is connected in the piping so that the water that flows into or out of the lifting cylinder passes through it. If, when the car is ascending, the water enters through port, *C*, and passes out through *D*, then on the descending trip the water will enter

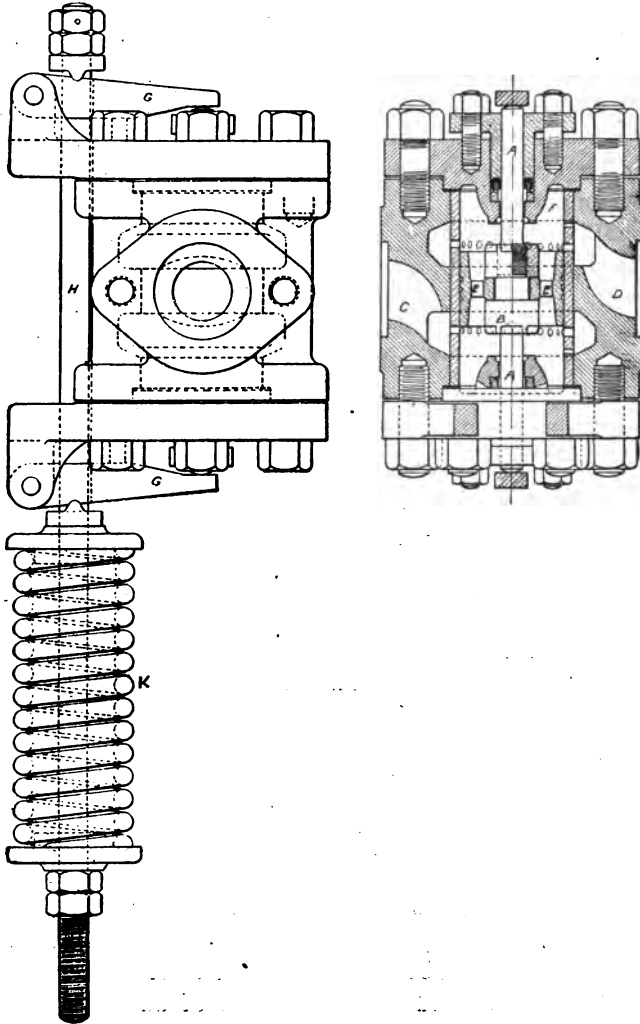


FIG. 41.

through *D* and pass out through *C*. In either case, the water will have to pass through the openings, *E*, in the valve piston, this passage causing a certain amount of loss in pressure dependent entirely upon the velocity of the water through the holes, *E*.

Suppose that, when the car is running at 400 feet a minute, the loss of pressure suffered by the water in passing through the piston holes, *E*, is 20 pounds; then, if the car is running up and the pressure of the water when it reaches one side of *B* is 800 pounds, it will be, on the other side, 780 pounds. If the car is running down and the water is discharging into the delivery tank, a pressure of 100 pounds on the cylinder side of *B* will correspond to 80 pounds on the tank side of *B*; that is to say, in either case the difference in pressure between the two sides of *B* will be 20 pounds.

From the construction of the device, it will be seen that the force with which the piston rod, *A*, is moved endwise by the difference in the pressure on the opposite sides of *B* is resisted by the spring, *K*, so that by properly adjusting this spring, the car can be made to run at any desired speed with the main valve wide open, regardless of the magnitude of the load or whether it is running up or down. Thus it will be seen that, when this speed regulator is provided, the car cannot attain an excessive velocity, even if the operator becomes confused and opens the main valve too wide.

In passing from either of the inlets, *C* or *D*, into the interior of the cylinder, the water must flow through the small holes in the casing, *F*. These holes are drilled on spiral lines so that, when *B* moves in either direction, it covers the holes one at a time, thus gradually closing the outlet. The end movement of *B* is transmitted to one or the other of the levers, *G*, through rod, *A*, and the movement of either lever will compress spring, *K*.

As has already been stated, the regular pressure tank is not used for the high-pressure system, but is replaced by an accumulator, on account of the difficulty of pumping air against high pressures and also because, with an accumulator the pressure can be maintained absolutely constant, which cannot be done with a pressure tank. If only one elevator is operated, the accumulator will have a capacity somewhat greater than that of the lifting cylinder, but when there are a number of elevators, the total accumulator capacity will not be proportionately increased. The high-pressure system is intended for large elevator installations where from five to ten or more cars are used, running continuously throughout a large portion of the day.

Owing to this fact, the pump capacity is made great enough to supply the water required when all the cars are in motion at the same time, and the accumulator capacity is considerably less than the combined capacity of the lifting cylinders. The number of accumulators is made equal to the number of pumps; thus, if there are fifteen elevators and three pumps, there will be three accumulators. Pipe connections are

made so as to combine all the lifting cylinders, accumulators and pumps into one general system, but there is a direct connection through rather short pipe lines between each of the pumps and one of the accumulators. The operation of each pump is controlled directly by the amount of water in the accumulator with which it is directly connected; that is, there is an automatic connection between the accumulator and the pump whereby the latter is stopped when the accumulator is full, and is

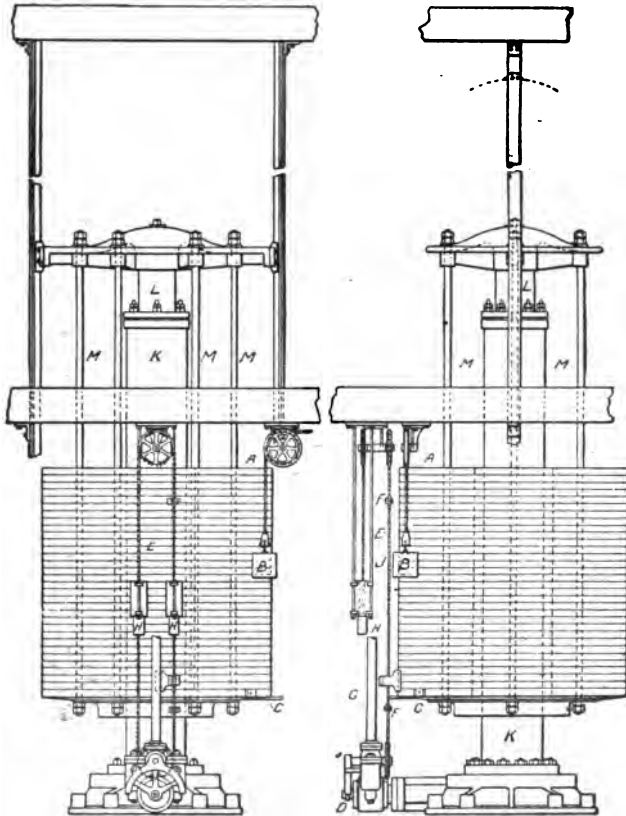


FIG. 42.

set in motion as soon as the accumulator plunger begins to descend. In addition, the accumulator is provided with an automatic safety valve that closes the inlet when the plunger reaches either the top or the bottom positions. This valve is provided so as to prevent the plunger from striking violently against the top and bottom stops, in case of failure of the automatic pump stop to act when the accumulator is full, or of a

drain on the supply greater, for any reason, than the pump can maintain.

An accumulator provided with an automatic pump stop, and an automatic valve stop is shown in Fig. 42. The rope, *A*, is connected with the starting valve of the pump and, so long as the weight, *B*, hangs free, the pump will run; but, when the accumulator plunger rises high enough for the shelf, *C*, to lift *B*, the pump valve will be gradually closed, the pump will slow down, and finally stop, if *C* rises high enough.

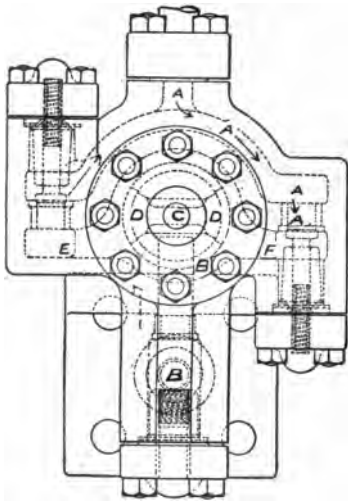
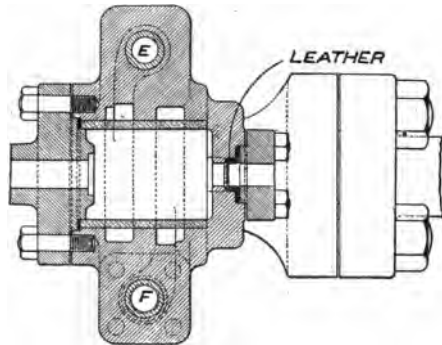


FIG. 43.

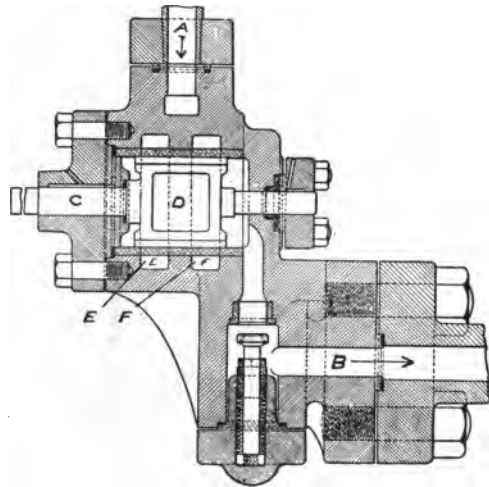


FIG. 44. FIG. 45.

At *D* is the automatic stop valve, which is actuated by the rotation of a sprocket wheel mounted on the end of the valve shaft, this wheel being turned by the chain, *E*. The arm projecting from the accumulator weights strikes the upper stop ball, *F*, when the plunger reaches the top limit and the valve, *D*, is rotated so as to prevent the entrance of water to the accumulator, but it will not stop the outward flow. If the

plunger is descending, the lower stop, *F*, will be struck, and then the valve, *D*, will be rotated in the opposite direction, so as to prevent the escape of water from the accumulator, but not to stop the inward flow. The construction of this valve is shown in Figs. 43-45.

Water flowing into the accumulator takes the course indicated by the

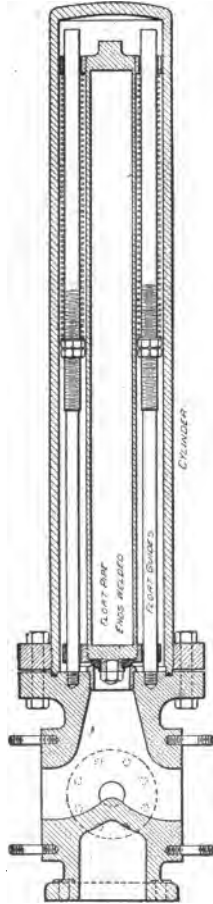


FIG. 46.

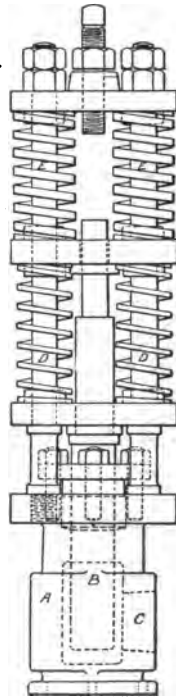


FIG. 47.

arrows, *A*, Fig. 43, and the course flowing out is indicated by the dotted arrows. As will be seen, the check valve on the inlet side, opens downward, and the one on the outlet side opens upward. If the valve, *D*, which is rotated by the movement of the chain, *E*, Fig. 42, is in the central position, water can flow freely through it in either direction. If *D* is rotated in one direction, it will stop off the passage through the

right-hand valve and, if it is rotated in the opposite direction, it will close the passage through the left-hand valve.

In the end elevation at the left, the arrows are drawn in a manner which might indicate that there is free access from chambers, *E* and *F* into *B*, but, from an inspection of the sectional views, it will be seen that the communication in both cases is through valve, *D*; hence, by the rotation of *D* in one direction or the other, the flow through the corresponding check valve is stopped.

When many elevators are operated from a general piping system, the sudden drain of water at one point may cause a temporary drop in pressure and thereby impart an unevenness of motion to the water flowing into the lifting cylinders. It is also possible for the pulsations of the pumps to pass beyond the air chambers attached to the pumps, when the demand for water is sudden. The air chamber shown in Fig. 46 is provided to smooth out any such unevenness in the flow of water into the lifting cylinders, so that the motion of the elevator car may be entirely free from tremor. This air chamber is constructed with a valve made in the form of a float and supported on springs so as to prevent too sudden closing. The upper part of the chamber is filled with air forced in under considerable pressure, this air acting to force down the valve when the pressure drops and permitting it to rise when the pressure increases. Air chambers of this kind are placed at several points in the line pipes, wherever their presence may be required.

Sudden stopping of elevators is liable to cause the water in the connecting pipes to surge back and forth with considerable force, thus producing water hammer effects. To counteract such action, the device shown in Fig. 47 is placed at the ends of long runs of pipe and acts as follows: If the current of water flowing in the pipe is suddenly arrested by the stopping of an elevator, the stream continues on to the end of the pipe where this spring accumulator is located and, entering, forces the plunger, *B*, upward against the pressure of springs, *D* and *E*. If the force of the water current is small, only the light spring, *D*, will be compressed, but if the force is sufficient both springs will be brought into action.

For the high-pressure system the general arrangement is shown in Fig. 48. The main valve is at *D* and the pilot valve at *P*. The way in which the pilot valve is connected with the operating lever in the car, through *NN* and *mm* is clearly shown. The rope, *A*, running from the accumulator to the pump valve, *B*, shows how the operation of the pump is controlled. The pipe, *C*, runs from the accumulator to the main valve, and pipe, *M*, connects with the discharge tank on the roof, from which tank the pilot valve is supplied. Pipe, *E*, connects the main valve

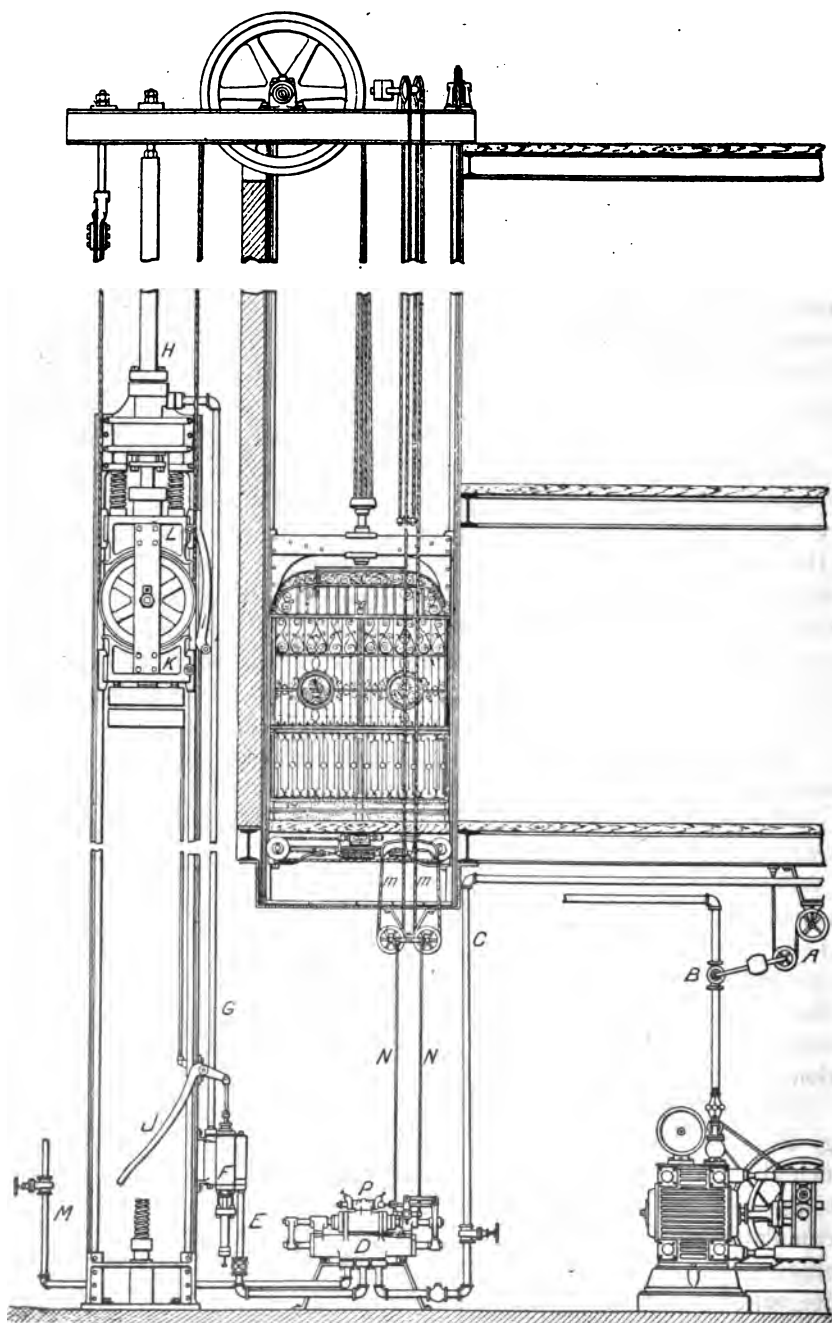


FIG. 48.

*D*, with the automatic stop valve, *F*, from which the pipe, *G*, leads to the lower end of the lifting cylinder, *H*. The stop valve, *F*, is not of the same form as the one shown in Fig. 40, the latter being a design of recent date, which, in addition to modifications in construction, is actuated in a different way. Valve, *F*, is operated through levers, *I* and *J*, by the rollers, *L* and *K*, mounted upon the frame of the traveling sheave. Lever, *I*, acts to depress the valve, *F*, while lever, *J*, lifts it. With the design shown in Fig. 40, the levers, *I* and *J*, and the rod connecting them are replaced by the chain and sprocket wheels referred to in the description, and the rollers, *L* and *K*, are replaced by an arm through the end of which passes the chain and which strikes stop balls in the same manner as is shown in connection with the accumulator stop valve in Fig. 42.

## CHAPTER IX.

## HORIZONTAL-CYLINDER HYDRAULIC ELEVATORS—PULLING TYPE.

**I**N THE preceding chapters we have described the various types of vertical-cylinder hydraulic elevators; we will now consider the horizontal-cylinder types.

Horizontal-cylinder hydraulic elevator machines are divided into two classes, the pushing and the pulling. In the first named, the piston is pushed out to the end of the cylinder so that the piston rod is subjected to a compression strain; in the second, the piston is moved in the opposite direction and thus the piston rod is subjected to a tensile strain.

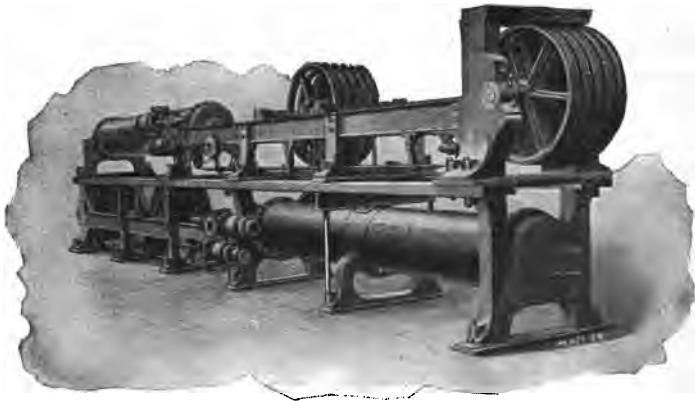


FIG. 49.

Fig. 49 shows the pulling type of machine, what is called a double decker, or two machines, one on top of the other. The sheaves and cylinders are so located that one elevator is operated from each end of the machine. In most cases, however, the sheaves of both machines are located at the same end and the lifting ropes are guided to their respective elevator cars by means of suitably placed overhead sheaves.

Fig. 50 is a side elevation and plan of the pulling machine made by the Whittier Machine Co., Boston, Mass. The lifting cylinder is shown at *A* and the piston rods can be seen at *B B*, secured into one end of the crosshead, *C*, which carries the traveling sheaves, *D*. The stationary sheaves are located at *E*, and when the elevator car is at the bottom of the well the traveling sheaves are close up to *E*. When the main valve is opened so as to lift the elevator car, the sheaves, *D*, are pulled toward

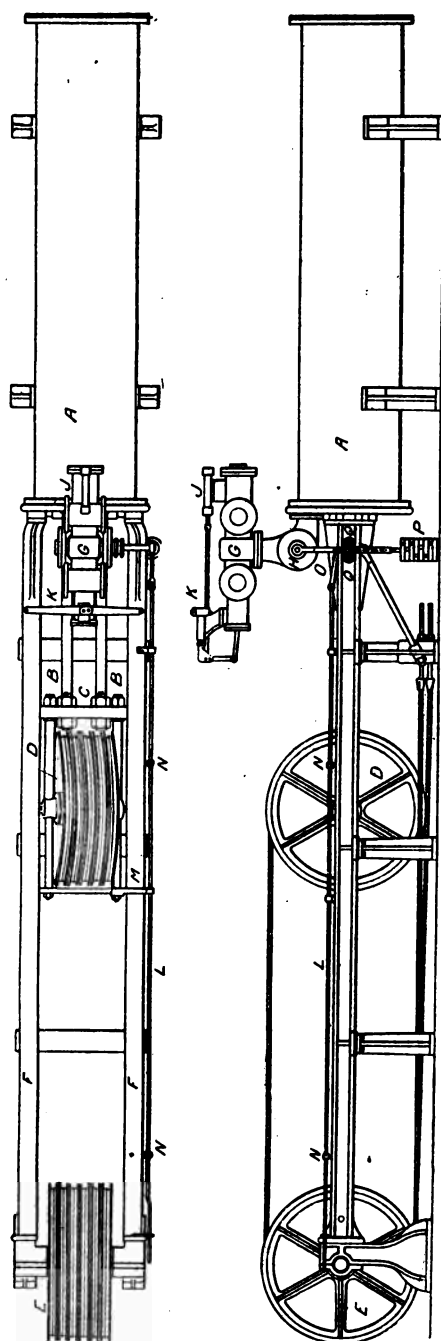
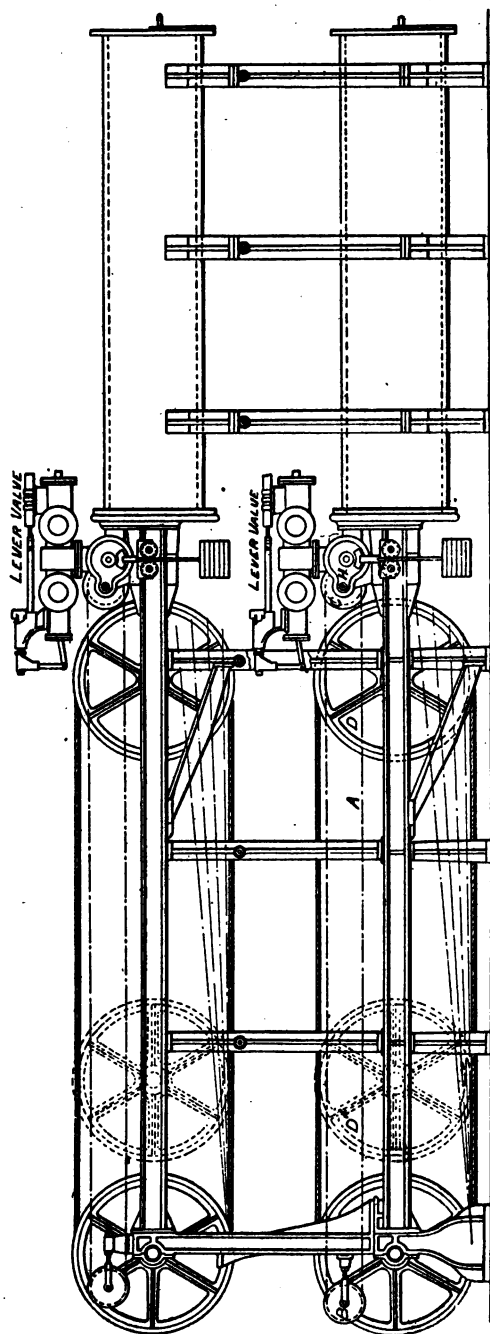


FIG. 50.



the cylinder by the piston rods, *B B*. The main valve is located at *G* and is actuated by a pilot valve at *J*.

At *H* is placed the automatic stop valve, which, in this particular design, is actuated by means of the rod, *L*, the stops, *NN*, and an arm, *M*, that projects from the crosshead, *C*, as clearly shown in the plan view. By striking one or the other of the stops, *N*, this arm, *M*, swings lever, *O*, of the stop valve to one side of the central position, thus stopping the flow of water in or out of the cylinder, *A*, as the case may require. When the traveling sheaves and frame, *C*, are not at one end or the other, the weight, *P*, suspended from *O* by means of the chain shown, draws the valve, *H*, into the central position, the rollers, *Q Q*, guiding the weight chain.

In buildings where a number of elevators are installed and floor room is limited, it is common practice to stack these horizontal machines two or three high. A double-deck machine is shown in Fig. 51, which drawing, in addition to showing the arrangement of decked machines, also serves to more clearly illustrate the operation, as the forward position of the traveling sheaves is indicated at *D'*. The main and the pilot valves in this drawing are the same as in Fig. 50, but the automatic stop valve is of a somewhat modified design and is arranged so as to be actuated by the rope, *A*, which passes around sheaves, *B* and *C*, the latter being mounted upon a shaft that carries a pinion which meshes into a gear secured to the end of the valve shaft. Stop balls are placed on *A* at proper points so that they may be struck by an arm projecting from the cross-head frame when the elevator reaches the top and bottom landings.

Construction of the main and pilot valves, and also the way in which the latter is moved by the operating lever in the car, are all clearly shown in the detail drawings, Figs. 52 and 53. The ropes, *AA*, are connected with the lever in the car, and thus the movement of the latter lever actuates the pilot valve lever, *E*. This lever swings around the stud *F*, and imparts an endwise movement to the pilot shifting rod and the head, *B*. The pilot connecting rod, *C*, is connected with *B* indirectly, through its connection with the lever, *D*, which leads to the main valve. As will be noticed, *D* is pivoted to *B* at *G*, and *C* is pivoted to *D* at *H*.

Operation of the valves is substantially the same as that of the vertical-cylinder valves that have been fully explained in previous chapters. When the movement of *B* shifts the pilot valve from the central position, water flows either into or out of the left-hand end of the main valve chamber, and this valve is thus moved either to the right or the left. Water from the high-pressure tank enters the main valve chamber at the right-hand end, so that, if the pilot valve is moved to the right, the water confined in the left-hand end of main valve chamber will

escape and the valve will move to the left, thereby permitting the pressure tank water to flow through the valve to the center port and thence to the lifting cylinder.

Movement of the main valve to the left will carry the pilot valve back to the central position and stop the further movement of the main valve, the operation being precisely the same as in the vertical-cylinder valve. The extent to which the main valve is opened is governed entirely by the distance through which the pilot valve is moved in the first instance.

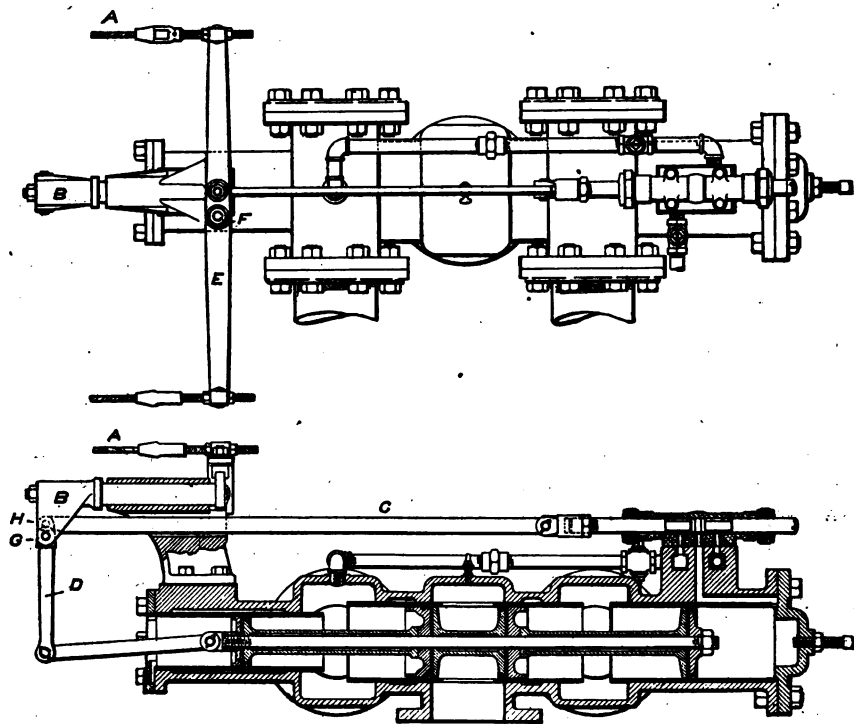


FIG. 52. FIG. 53.

The pilot shown in Figs. 52 and 53 is not the design furnished with machines installed at the present time, but it operates in the same manner. The latest design of pilot valve is shown in Fig. 54; in comparing the drawings, it will be seen that the difference is wholly in the way in which leakage is prevented. In the earlier design, this result was attained by providing stuffing boxes at each end of the valve cylinder, while in Fig. 54 cup packings are provided at each end of the valve. In the first design the valve proper is made tight at the ports by grinding to form a close

fit, the valve itself being a solid plug. In Fig. 54, the valve is made tight at the ports by being provided with cup packings.

Details of construction of the automatic stop valve, *H*, Fig. 50, are shown in Fig. 55, showing vertical sections at right angles to each other. When water is flowing into the cylinder, the valve carrier, *A*, rotates clockwise, so as to carry the valve, *B*, over port, *C*. This is

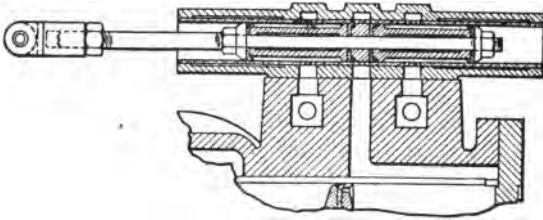


FIG. 54.

the direction of movement when the car reaches the upper landing. When the water flows out of the cylinder, the carrier, *A*, rotates counter-clockwise, so as to carry the valve, *B*, over port, *D*.

It will be seen that, into whichever position it is shifted, the valve will make a tight fit only when the water is flowing in such a direction as to force *B* away from the center. This is the direction of flow of

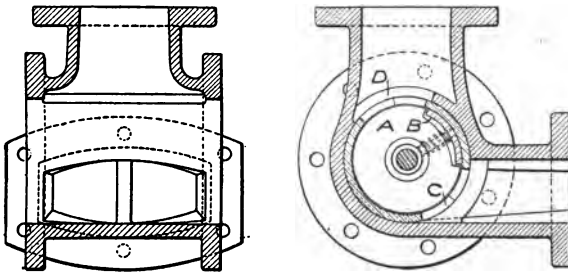


FIG. 55.

the water when the valve closes, but when the main valve is reversed, so as to reverse the direction of travel of the elevator, the pressure of the water will force valve, *B*, toward the center and thus allow water to leak by it, the amount being sufficient to start the elevator slowly. As soon as the elevator moves, the carrier, *A*, begins to move back to the central position, thus opening the valve wide. This action is the same as that of the automatic stop valve used in the high-pressure system, fully explained in Chapter VIII.

For the piston of the lifting cylinder the construction is shown in detail in Fig. 56, from which it will be seen that the piston consists of a main body and a ring-shaped follower, the latter being drawn up by means of nuts on the studs, *C*. The packing is held in the annular space, *A A*. It is desirable that the piston of a horizontal-cylinder machine be made as light as possible consistent with strength, so as to reduce the friction to the lowest point, and also for the purpose of preventing excessive wear on the lower sides of cylinder and piston. It is on this account that the follower, *B*, is made in the form of a ring of light construction, and the body proper of the piston consists of an outer ring, the interior of which is closed up by a web, strongly braced by transverse ribbing. The piston rods are secured into the holes, *D D*, the end of one rod being shown in position.

Horizontal-cylinder machines are sometimes equipped with simple or direct-acting valves, when the speed of the car is low enough to enable

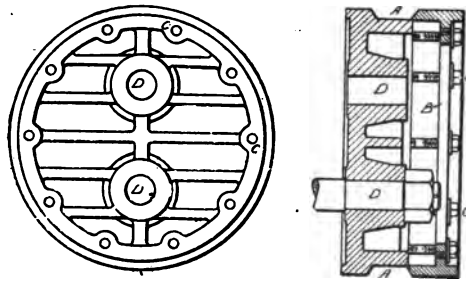


FIG. 56.

the operator to control its movement with certainty by means of a hand rope. Several years ago, before car levers and pilot valves were introduced, all the elevators of this type, as well as the vertical machines, were provided with such valves, and, as there are many such machines in use at the present time, we will describe the type of valve with which they are equipped.

Fig. 57 shows the valve and valve chamber used with the Whittier machines for hand rope control. The valve is placed in the same position as the main valve in Fig. 50, the flange, *B*, being bolted to the top of the automatic stop valve, *H*. One of the inlets, *C C*, is closed up with a flange, and to the other is connected the pipe coming from the pressure tank. A sheave wheel is mounted upon the end of the shaft, *A*, and around this sheave the operating hand rope is wound. With the valve in the position shown in Fig. 57, water cannot enter or escape from the cylinder; hence the elevator will not move.

If *A* is rotated clockwise, the valve is shifted to the left; then the inlet is connected with the cylinder port and water passes into the

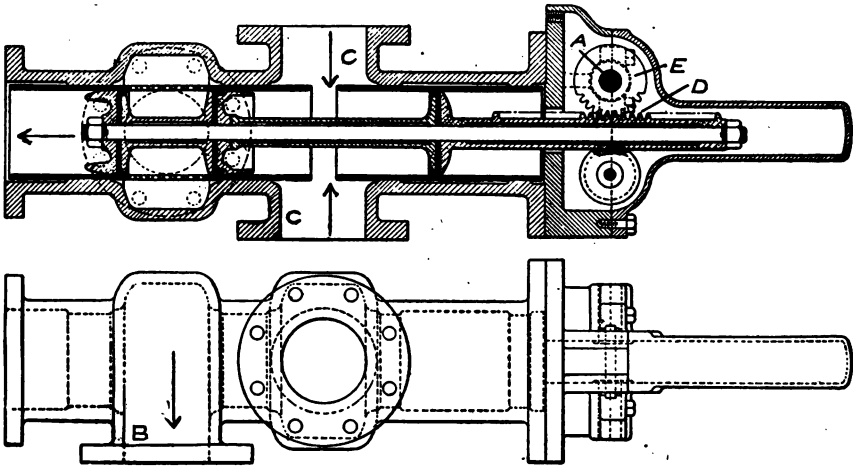


FIG. 57.

cylinder, causing the elevator car to ascend. If *A* is rotated in the opposite direction, the cylinder port is connected with the discharge;

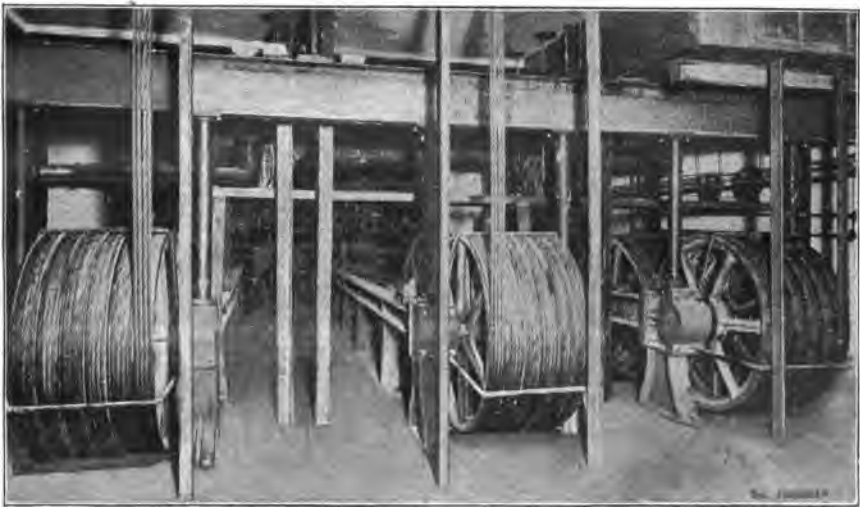


FIG. 58.

then water escapes from the cylinder, and the elevator descends. The pinion, *E*, on *A*, as well as the rack, *D*, on the end of the valve rod, are

shown with only a few teeth, but the rack has teeth throughout its entire length and the pinion is cut all the way around the circumference. In moving the valve through its whole stroke, the shaft, *A*, is rotated nearly one complete revolution, and stops are provided to prevent moving it beyond this point.

Covering is provided over the rack and pinion simply as a protection,

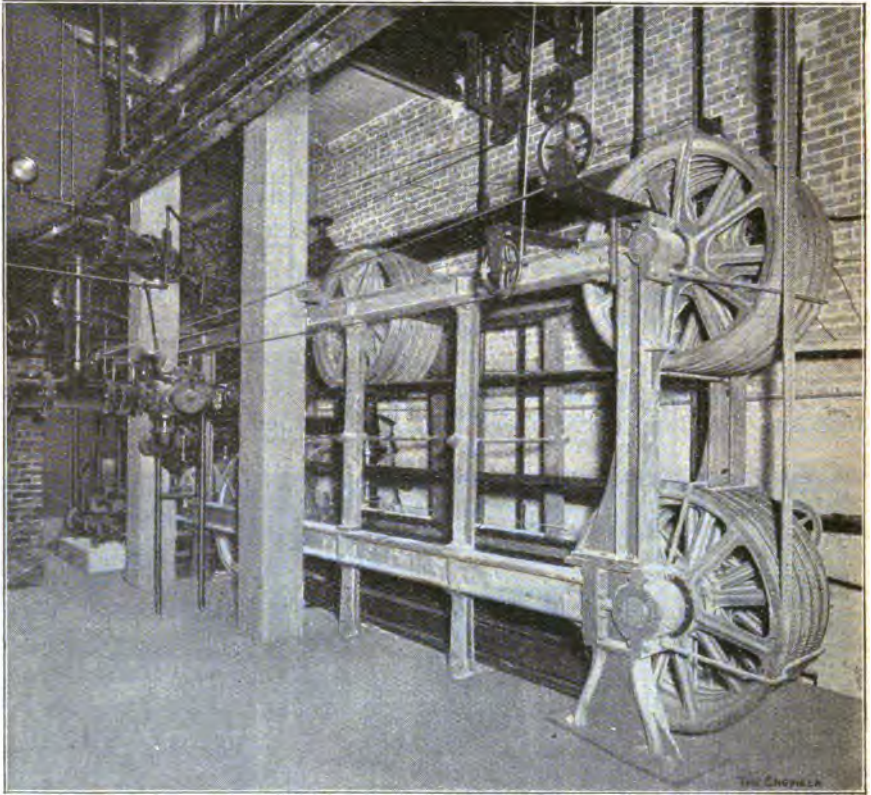


FIG. 59.

and not to prevent the escape of water; in fact, this casing is not water tight. If the valve is in proper condition, water does not reach the rack chamber, as it cannot pass beyond the cup packing to the right of the inlet ports.

For the Whittier horizontal machines the general appearance is shown in Figs. 58 and 59, which are from photographic views taken in buildings in Boston in which these elevators are in daily operation.

Fig. 58 shows three machines placed side by side. Fig. 59 presents two machines, one above the other, a double-decker. In both these views the stationary sheaves are at the front and the lifting ropes are seen running up into the elevator well. In both cases the machines are placed below the bottom elevator landing, but in some buildings the elevators run down to the floor on which the machines are located, and on that account the construction is made so that all parts of the machine are back of the front side of the sheaves, so that there may be nothing projecting into the path of the elevator car.

Vertical-cylinder hydraulic elevators are made so as to be geared from two to one to six to one, as has been fully explained in previous chapters. Horizontal machines, however, are always geared much higher. In vertical machines, low gears are used because there is no objection to making the cylinders long, within certain limits; but with horizontal machines there is an objection to long cylinders, as they occupy too much floor space, which in most buildings is valuable and in some cannot be had. It is for the purpose of economizing floor space that the machines are decked two and three high, and for the same reason the gear is always made greater than with vertical machines. The gears most commonly used for horizontal machines are eight, ten and twelve to one.

## CHAPTER X.

## HORIZONTAL CYLINDER, HYDRAULIC ELEVATORS, PUSHING TYPE.

**B**ETWEEN the pulling and the pushing types of horizontal hydraulic elevator machines the difference is that in the former the traveling sheave is pulled toward the cylinder by the pressure of the water acting upon the piston, while in the latter type the traveling sheave is pushed away from the cylinder. Owing to this difference, the stationary and the traveling sheaves are both located at one end of the machine in the pulling type, while in the pushing type the stationary sheaves are placed at one end and the traveling sheaves at the other. The appearance of the pushing type of horizontal hydraulic elevator machine is well

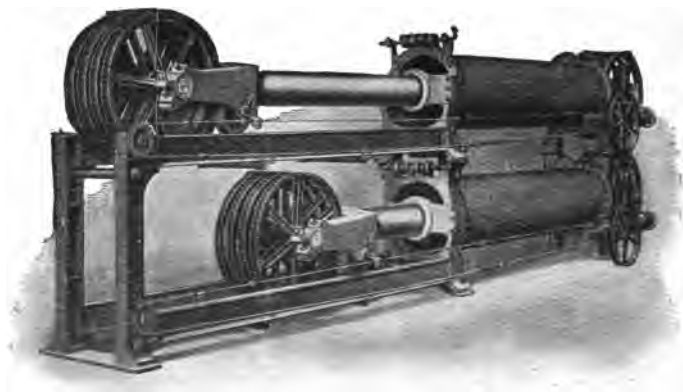


FIG. 60.

shown in Fig. 60, which is a photographic view of a double-decker. The location of such machines with reference to the elevator well, and the way in which the controlling ropes are connected with the car lever and the pilot valve is clearly shown in Fig. 61. Fig. 62 is a side elevation of the machine made at the Chicago shops of the Otis Elevator Co. Fig. 63 is a vertical section through the elevation Fig. 62.

Figure 62 shows not only the construction of the machine, but also its location with reference to the elevator well. In addition it illustrates clearly the way in which the pilot valve lever, *N*, is connected with the operating lever in the car; and shows the plan outline of the elevator well and also the location of the overhead sheave and the supporting frame work.

The valve gear used with these machines is of a somewhat different

design from that used with the Whittier machines. The pilot valve is located at *M* and the main valve is within the casing, *LL*. The automatic stop valve is at *K* and is actuated through the rod, *J*, in the following manner: The double arm lever, *GH*, with which *J* is connected is rotated through a sufficient angle to close the valve, *K*, by means of rollers carried by the frame, *F*. This latter frame is attached to the

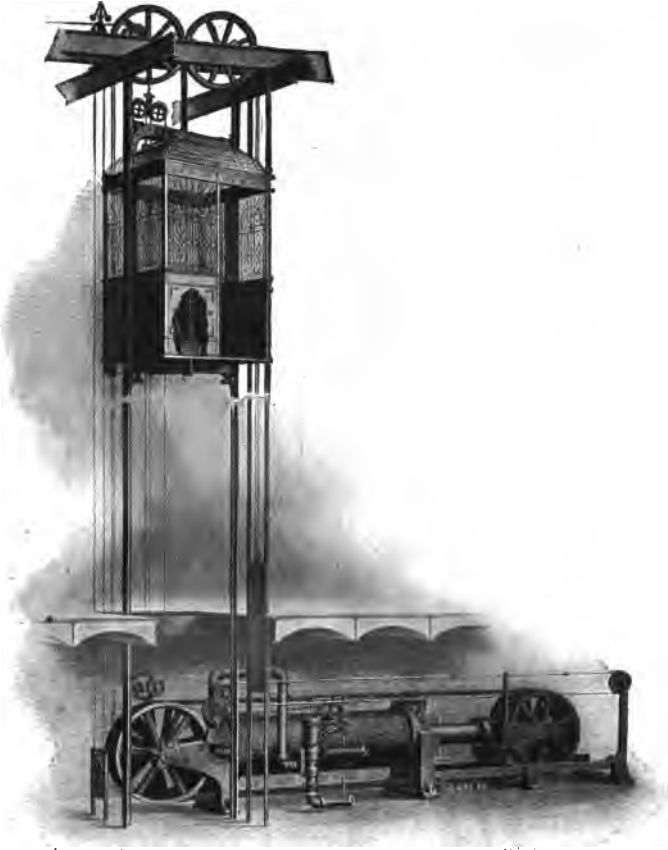


FIG. 61.

end of a rod upon which the stops *CD*, are fastened. From the frame of the traveling sheave an arm, *E*, projects and surrounds the rod on which *C* and *D* are mounted. When the traveling sheaves, *B*, reach either end of their travel, one or the other of the rollers on *F* will strike one of the arms, *G* or *H*, and swing the lever in a counter clockwise direction, thus drawing rod, *J*, to the right, and thereby closing the auto-

matic valve, *K*. The construction of *K* will be explained presently, but before doing this, we will describe the construction of the main and pilot valves, which are shown in Figs. 64 and 65, the first being a vertical elevation in section, and the second a vertical end elevation. The shipper

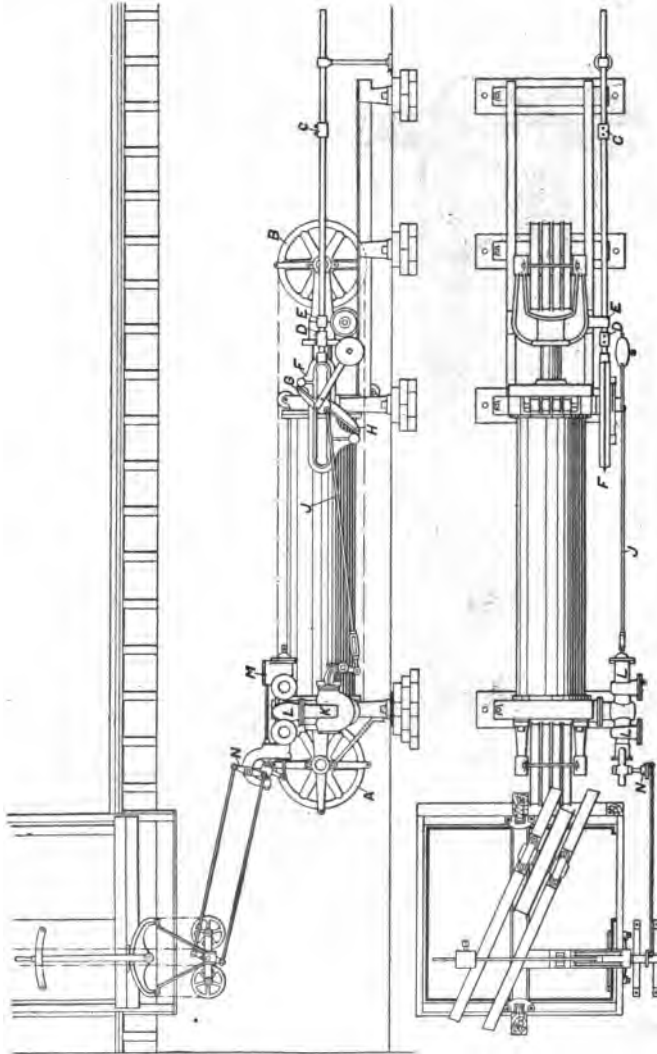


FIG. 62.

bar for operating the pilot valve, as can be seen in Fig. 64, differs slightly from the construction of Fig. 62, the main difference being that the latter is provided with an additional overhanging bearing. In all other respects the designs are identical. From a close inspection of Fig. 64

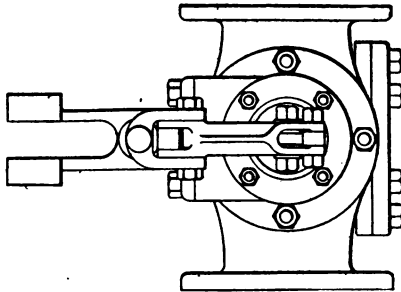


FIG. 65.

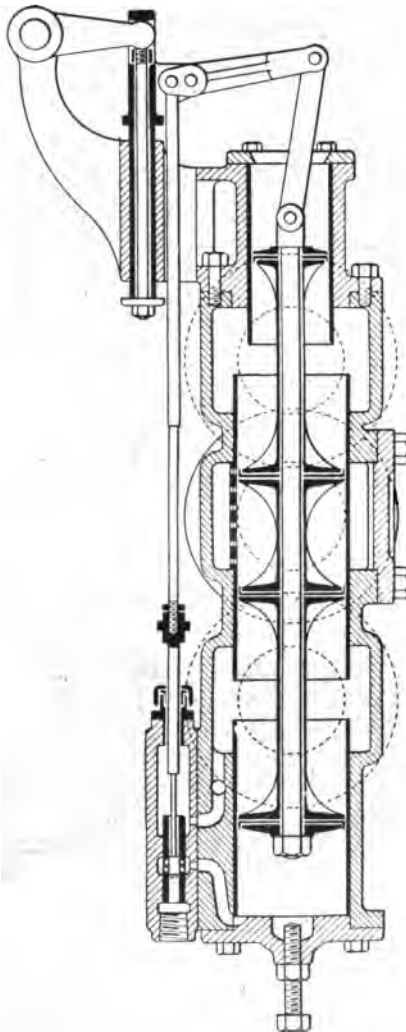


FIG. 64.

it will be seen that the main as well as the pilot valve, are arranged to operate in the same manner as the valves used with the Whittier machine,

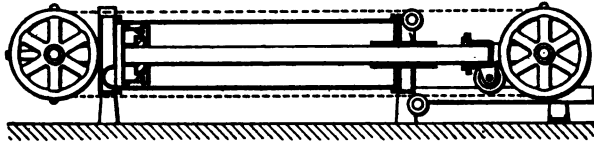


FIG. 63.

and as the latter was fully explained in the last chapter, it will not be necessary to give a detailed description here.

Figure 66 is an end view of the main cylinder, the main valve and

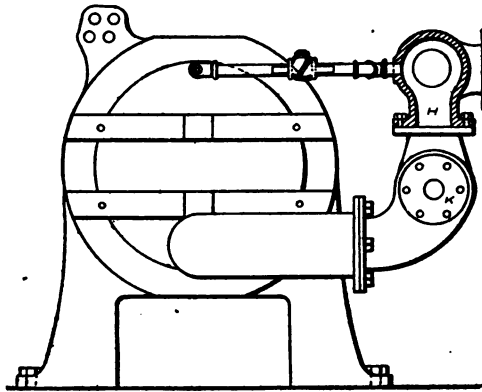


FIG. 66.

the automatic stop valve, *K*, from which the relative location of the valves and their position with reference to each other and to the cylinder can be understood.

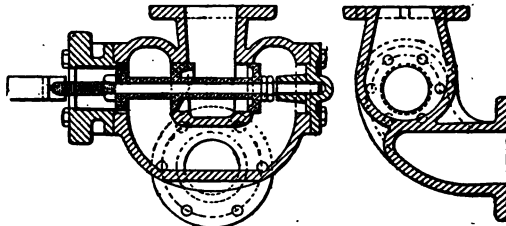


FIG. 67.

The construction and operation of the automatic stop valve *K* can be understood from the details Fig. 67. The drawing shows two sections through the valve and valve chamber, and taken at right angles to each

other. As will be seen from this figure, the valve moves endwise in the valve chamber and, when it is in the position drawn, the upper part of the valve chamber is separated from the lower. The main valve rests upon the upper flange and the lower flange is bolted against the main cylinder as is more clearly shown in Fig. 66. From this it will be understood that the rod, *J*, in Fig. 62, when drawn toward the right pushes the valve in and thus closes it. To avoid confusion it may be well to say that the position of the valve and chamber in Fig. 67 is the reverse of that in which it is shown in Fig. 62, so that, while in the former, moving the valve toward the left would open it, in the latter, movement in this direction forces it into the chamber and closes it.

Pushing machines are decked as shown in Fig. 68, which is a vertical elevation and plan of a three deck machine. These drawings are specially instructive because in addition to showing the general arrangement of the machines themselves, they show their location with respect to the elevator well, the way in which the overhead sheaves are disposed and supported, the location of the car counterbalances and the position of the elevator cars in the wells corresponding to given positions of the traveling sheaves. It will be seen that the elevator car on the left is at the top of the well. This car is operated by the top machine the traveling sheaves of which are at the extreme right-hand position. The middle car is in a position intermediate between the top and bottom, and the middle machine which operates this car has its traveling sheaves in a position midway between the extreme right and left positions. The right-hand car is shown at the bottom of the well, and the lower machine which operates it is shown with the traveling sheaves in the extreme left position.

Looking at the top machine it will be seen that the shipper frame is drawn to the right and that the lower roller has carried the automatic stop valve lever with it, thus stopping the machine automatically. Looking at the lower machine we find that the shipper frame is moved to the left and that the top roller has carried the upper arm of the automatic stop valve lever with it. Thus in both these machines the automatic stop valve lever is moved into the same position, but in the upper machine the movement is effected by the lower roller on the shipper frame while in the lower machine it is effected by the upper roller. In both cases, however the stop valve is moved in the same direction.

In the middle machine neither roller on the shipper frame is in a position to move the stop-valve shifting lever; hence, the valve remains open and the car is free to run under the control of the main operating valve and its pilot valve. The rope connections between the pilot valve

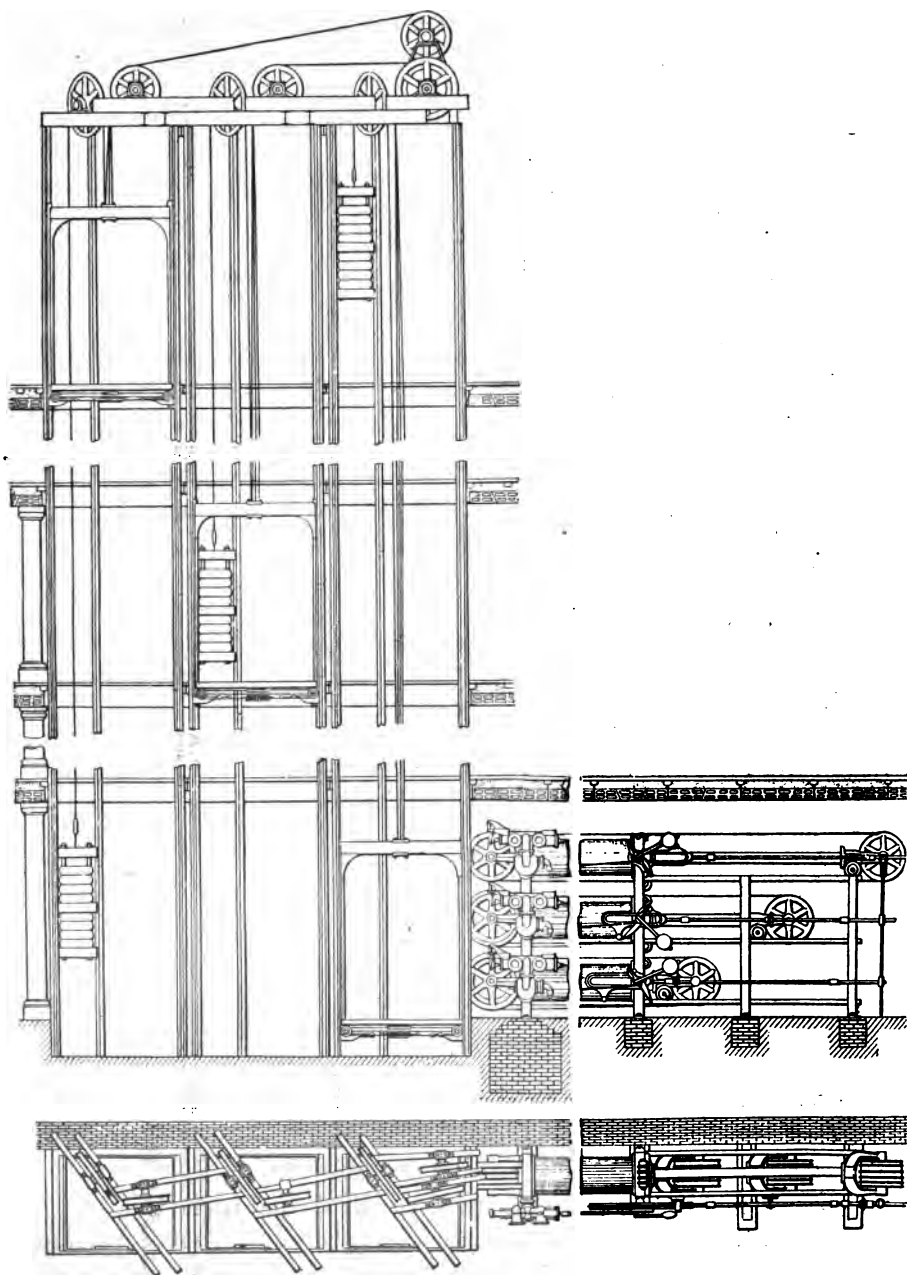


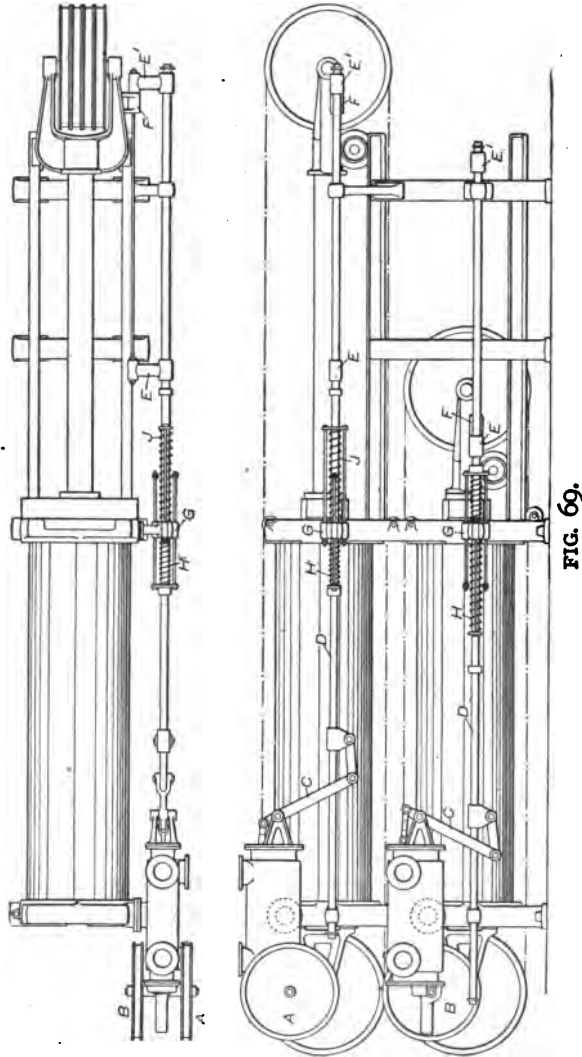
FIG. 68.

and the car are not shown but they can be readily understood as they are fully shown in other illustrations.

At the top of the vertical view and the left side of the plan view, the way in which the overhead sheaves are located so as to lead the lifting ropes to the elevator cars, the positions of the counterbalances and the sheaves over which the counterbalance ropes run and the arrangement of the framing for supporting the overhead work are fully shown. The lifting ropes run straight up from the stationary sheaves of the machines, one passing up from the sheave on the valve side of the machine, and two from the sheaves on the opposite, or wall side. Owing to this arrangement the overhead sheaves for the left side and the middle elevators have to be set one above the other, as is shown in the elevation. This being the case, the ropes from the upper and the middle machines have to run side by side, and in order that they may not rub against each other, the sheave of the top machine is made of smaller diameter than that of the middle machine. For the purpose of having the ropes in line with each other, the sheave of the lower machine on the valve side, is made of the same diameter as the leading off sheave of the middle machine. In the plan it will be seen that the two outside sheaves are of larger diameter than the three intermediates. Both large sheaves are not on the same machine, the one next to the wall is on the middle machine, and the one on the valve side is on the lower machine. On the top machine all the sheaves are of the same size. The fact that only the two lower machines have enlarged side sheaves is clearly indicated, for the ropes are shown running from the traveling sheaves on the right to, and around the small sheaves, and also around the large one which is the last, or leading off sheave.

There are many horizontal-cylinder machines in use, of the type described in this article, which are not provided with a pilot valve and car lever control, but are equipped with a hand rope and simple operating valve which is moved directly by the hand rope. A double decked machine provided with this type of valve is shown in Fig. 69, which is a side elevation and plan. The valve of the top machine is moved by a hand rope that passes around sheave, *A*, and the bottom machine valve is actuated by a rope that passes around sheave, *B*. In order that the hand ropes may not interfere with each other, they are mounted on opposite sides of the valve as can be readily understood from an examination of the plan view in Fig. 69 and also from Fig. 70, the latter being an enlarged end view of the machines taken from the right of the elevation Fig. 69. The main valve has an extended rod made in the shape of a rack, and upon the hand rope sheave shaft is a pinion that meshes into this rack so as to move the valve. This construction is substantially the

same as that of the simple vertical cylinder valve. Above the main valve is located the automatic top and bottom stop valve which is actuated through the shipper rod, *D*. When the elevator is running anywhere between the top and bottom landings, the lever, *C*, is in the vertical



position, and the stop valve is opened. The rod, *D*, and lever, *C*, are held in central position by the tension of the two springs, *J* and *H*, which press against the guide bracket, *G*. When the traveling sheaves are at the extreme right side, as shown in the top machine, the projection, *F*,

on the sheave frame carries *E'* on the right-hand end of shipper rod, *D*, with it and thus the lever, *C*, is moved to the right and the stop valve is carried into the position that stops the flow of water into the cylinder. As soon as the sheaves begin to move to the left, on the return stroke, the spring, *H*, which is compressed, extends and thus returns *D* and the lever, *C*, to the central position. When the sheaves move to the left, as

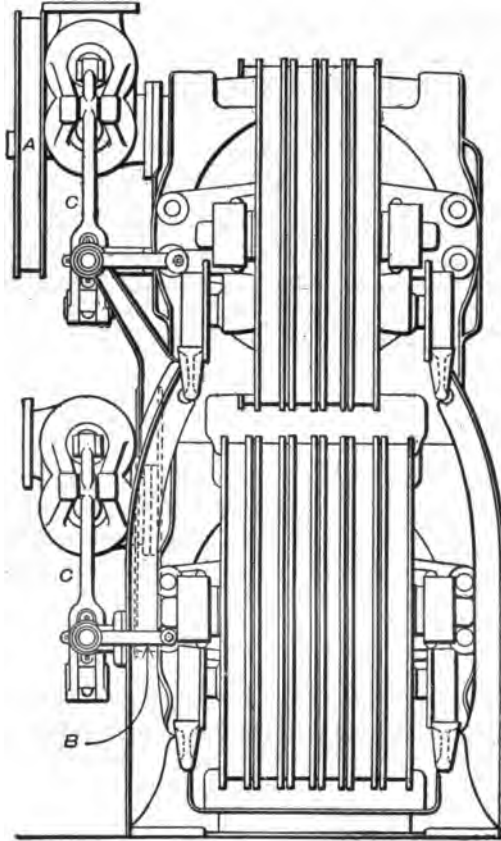


FIG. 70.

in the bottom machine, the projection, *F*, carries the left-hand arm, *E*, with it and thus moves lever, *C*, to the left, and compresses spring, *J*. The movement of *C* to the left carries the stop valve into position to prevent water from escaping from the cylinder. Thus the movement of *C* to the right shuts off the inlet to the cylinder, and its movement to the left shuts off the outlet.

The actual construction of these valves is shown in Fig. 71, which is

a longitudinal section through the valves and chamber, and an end view taken from the left side. In this figure, it will be seen that the lower valve is actuated by the rotation of the hand rope sheave, *A*, which turns the pinion that meshes into the rack on the end of the valve stem. With this valve in the position drawn, the water in the cylinder cannot escape into the discharge pipe, and water cannot enter the cylinder from the pressure tank. If the valve is moved to the right, *E* will uncover the cylinder port and allow the water to escape. If the valve is moved to the left, *D* will uncover the cylinder port and water will flow in from the supply pipe. These actions will take place, if the stop valve on top

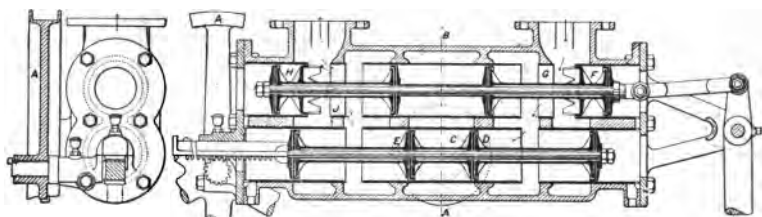


FIG. 71.

is in the position drawn, but if, when water is flowing into the cylinder from the supply pipe, lever, *C*, is moved to the right so as to move *F* to the left, then this valve will stop off the passage from the supply pipe and the elevator will stop as no more water can enter the cylinder. If the lever, *C*, is moved to the left, *H* will be moved to the right so that, if water is passing out of the cylinder, its flow will be stopped as *H* will close up the opening through *J*. The arrows indicate the path through which the water flows in and out of the cylinder when the main valve is moved in the proper direction, and the movement of the stop valve is always in the proper direction to close off the communication.

## CHAPTER XI.

## HYDRAULIC PLUNGER ELEVATORS.

**P**LVNGER elevators are direct-acting, the cylinder being placed in a vertical position under the center of the elevator car, the latter resting upon the upper end of the plunger. For a long time this type of elevator has been used for short runs, but it is only within recent years that it has entered the field as a competitor of the vertical and horizontal machines for high runs in office buildings, and for all classes of service, passenger as well as freight, and all car speeds from the lowest to the highest. As the machine is direct-acting, the plunger must be of a length somewhat greater than the height to which the car rises. Thus, if the run of the car is 150 feet, the plunger must be some more than this, say 155 feet, and the cylinder will have to be slightly longer than the plunger.

As the elevator car runs, generally, from the ground level or nearly so, the cylinder must be placed in a hole sunk into the earth to a depth equal to the run of the car. At first glance this fact might appear to limit the height of buildings for which this type of elevator is adapted, and may have been one of the principal reasons that deterred earlier builders from attempting to use plunger machines for high runs; but at the present time, it is not regarded as a serious matter by manufacturers.

In plunger elevators, as the full pressure on the end of the plunger acts to lift the car, the diameter of the plunger is much smaller than in the geared types of elevators. The pressure used varies from about 140 to 200 pounds per square inch and the diameter of the plunger may be from 5 to 7 inches. The cylinder is made of steel pipe about 2 inches larger in diameter than the plunger, and the hole in the ground is a couple of inches larger than the cylinder. It will thus be seen that the hole in which the cylinder is placed is not very large, so that it can be bored in a manner similar to that employed for driving pipe wells. If the subsoil is earth, a steel pipe lining is provided which is large enough to receive the cylinder. If the hole is drilled in rock, no lining is required.

For the cylinder, a number of lengths of steel pipe are turned true on the ends, threaded in a lathe, and joined by sleeve couplings. The upper end of the cylinder is screwed into a cast-iron section which is bored to fit the plunger, and is provided with a stuffing-box and a pipe connection through which the water enters and passes out of the cylinder. The lower end of the cylinder is closed by means of a suitable cap. The

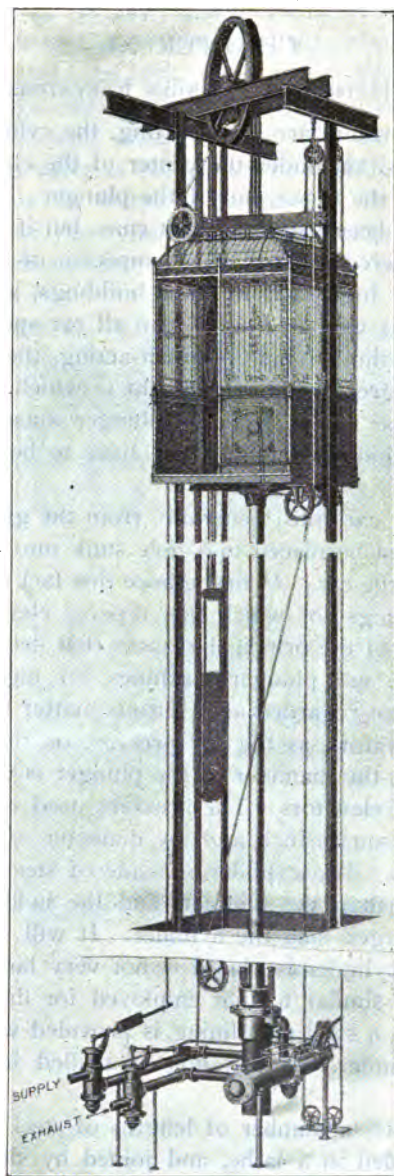


FIG. 72,

cylinder is coated with a protecting paint and when in position, the space between it and the sides of the hole is filled with sand.

For the plunger, a number of lengths of steel pipe are turned true and well polished. The sections are joined by means of long internal sleeves which are so proportioned that the transverse strength of the plunger at the joint is as strong as at any other point.

A general idea of the construction and operation of a plunger elevator can be obtained from the half tone, Fig. 72, which shows in perspective a first-class passenger elevator, a line drawing of the same being shown in Fig. 76.

From Fig. 73, which is a vertical elevation of a freight elevator as constructed by the Plunger Elevator Co., of Worcester, Mass., the general arrangement of a plunger elevator can be understood.

In looking at Fig. 73, it can be seen that the plunger must be long enough to push the elevator car to the top of the building. If this height is say 150 feet, and the plunger is only 6 inches in diameter, it might seem that the plunger would bend sidewise, if a moderate load were placed on the car. As a matter of fact, however, the plunger does not spring out of true to a noticeable extent even with a load greater than can be lifted. One reason why the plunger stands up so well under a load that would appear to be sufficient to buckle it out of shape is, that the counterbalance relieves it of a large portion of the strain.

If the plunger is 150 feet long, it will weigh so much that a portion of it will have to be counterbalanced, so that a considerable portion of the upper end is actually in tension when the load in the car is light, and even when the load is heavy, the pressure on the upper end of the plunger is not great, being, in fact, considerably less than the live load in the car. As the counterbalance weight is heavier than the empty car, the plunger has to be securely fastened to the under side of the car floor, which is accomplished by providing a framing of light I beams to which the head of the plunger is firmly bolted.

As the plunger, even if it buckled, would not permit the car to drop, the only possible way in which the latter could fall would be by the bursting of the cylinder. But even such an accident would not allow the car to drop, because the water would not escape fast enough from the cylinder to let the car descend at a high velocity, owing to the fact that the sand that fills the space between the cylinder and the sides of the hole in the ground would check the flow of water. Owing to these facts it is practically impossible for a plunger elevator to drop, and on that account no safety devices are attached to the car, as they are wholly unnecessary. It is undoubtedly owing to the feature of safety that this type of elevator has so rapidly grown in popularity.

As the elevator shown in Fig. 73 is a freight machine it is provided with a simple valve, actuated by means of a lever and starting rope. In another type, the valve is actuated by means of a rack and pinion, the

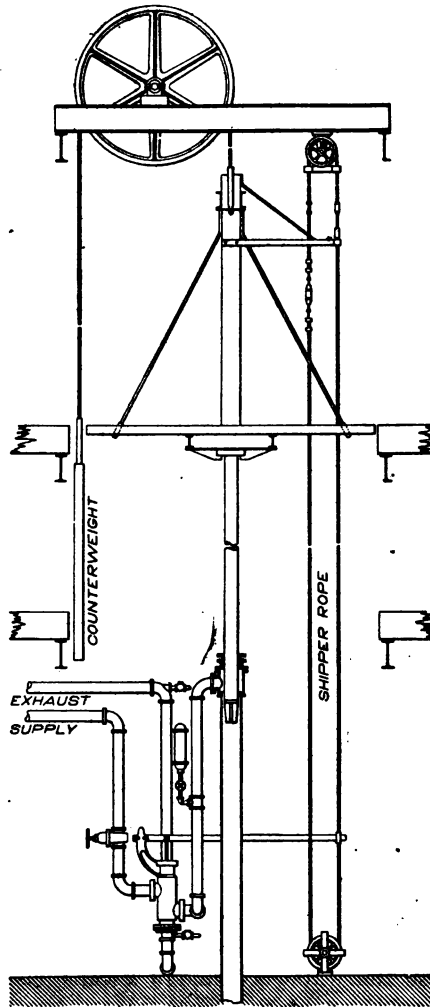


FIG. 73.

latter being rotated by a hand sheave, mounted upon the end of the shaft and around which the shipper rope is wound. In both these cases the car is stopped automatically at the top and bottom landings by means of the stop balls fastened to the hand rope as is clearly shown, these balls being

adjusted in position to be struck by the arm attached to the car at the proper time to bring the platform to a state of rest on a level with the floor.

In Fig. 74 is shown in section the valve of Fig. 73. It will be seen that the supply water acts against the under side of piston, *A*, and the upper side of *B*, so that the valve is perfectly balanced in-so-far as the pressure of the supply is concerned. If the delivery tank is placed at an elevation considerably above the lower side of *B*, and the part below point *D* be omitted, there will be a back pressure acting to push the valve upward, so that the force required to lift the valve will be less than that for depressing it. With the construction shown, it matters little where the discharge tank may be placed, for whatever back pressure may be in the exhaust, will bear equally upon the under side of *B* and the top of *C*, thus leaving the valve perfectly balanced. The cheaper

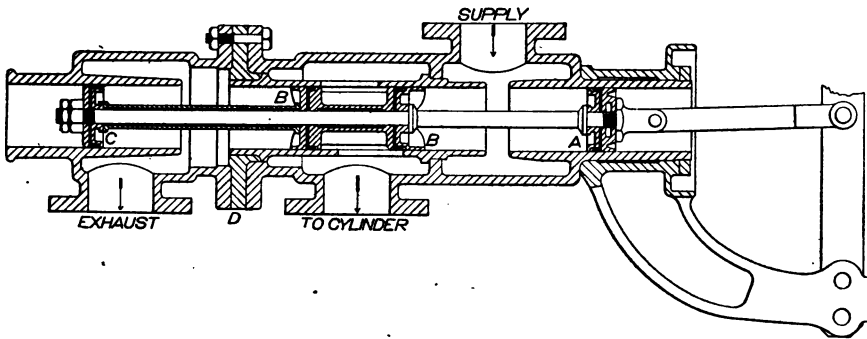


FIG. 74.

construction can, however, be used satisfactorily with the rack and pinion control.

Fig. 75 shows in plan and elevation the arrangement of the plunger elevator for cases where the platform is free of overhead framing, as for sidewalk elevators.

Fig. 76 is an elevation of a first-class plunger elevator for passenger service, as constructed by the Plunger Elevator Co. For this class of service, the main operating valve is arranged to be actuated by a pilot valve, which is moved by means of a lever, *L*, in the car. The general arrangement for the pilot valve system is the same as that used for vertical and horizontal hydraulic elevators, but in the details of construction and operation of the valves, there is a considerable difference. In addition to the main operating valve, and the pilot valve, top and bottom limit valves are provided by means of which the car is stopped automatically at the

upper and lower landings. As shown in the drawing, the up limit valve is actuated by the sheave, *N*, mounted on top of the car, which by putting a short bend in the valve rope lifts the operating lever of the valve. In like manner the sheave, *M*, draws up the lever of the down limit valve when the car descends to the lowest floor.

Ropes for actuating the pilot valve are somewhat different from those shown in connection with vertical and horizontal elevators. The

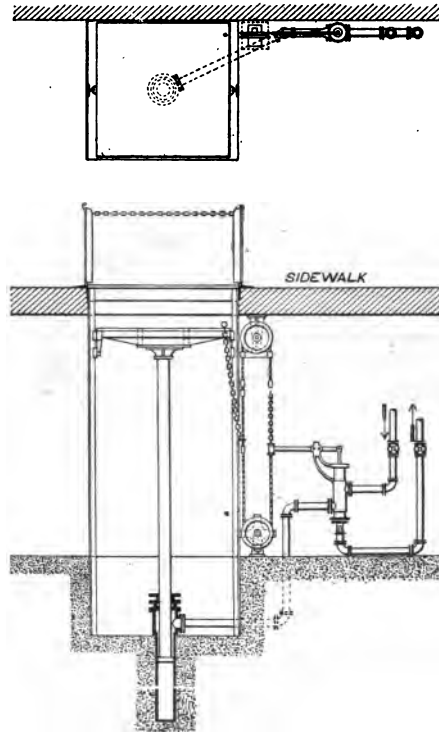


FIG. 75.

ropes, *O P*, pass under and over the sheaves, *R R*, so as to cross from one side to the other, as shown. When lever, *L*, is moved to the left, the right side sheave, *R*, rises and the other one moves down and thus the rope, *P*, is lifted and pulls up the pilot valve lever. When *L* is moved to the right, the right side sheave, *R*, moves down and rope *P*, moves with it thus depressing the pilot valve lever. The weights attached to the ends of these ropes are heavy enough to overcome the friction of the pilot valve and thus keep the ropes taut.

Fig. 77 is a sectional view of the valve shown in Fig. 76. Pipe, *A*,

Fig. 76, connects the supply pipe, through the limit valve, with the ports 27 and 14, shown in Fig. 77. In like manner the pipe, B, Fig. 76, connects the discharge pipe, through the down limit valve, with port, 15. The ports, 24 and 28, are connected with each other by a pipe as is clearly shown in Fig. 76. The operation of the valves is as follows:

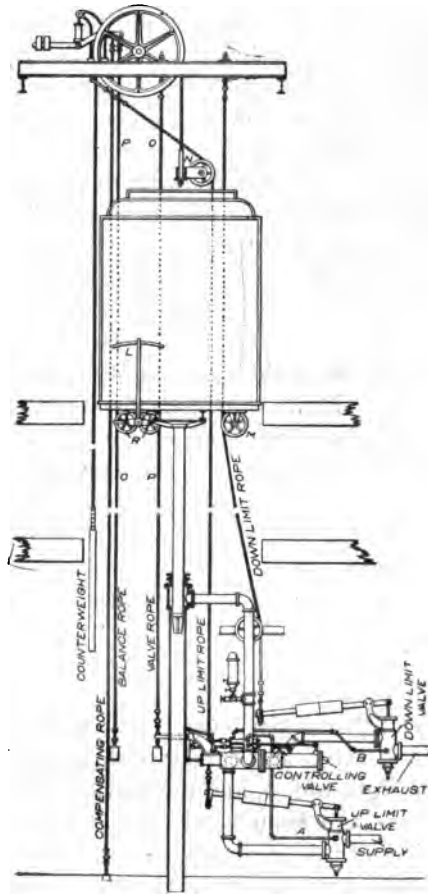


FIG. 76.

When the elevator is stopped, all the valves are in the position shown in Fig. 77, and the space between valves, 1 and 2, is filled with water under pressure, this space being permanently connected with the supply pipe as shown in Fig. 76. The supply pipe is connected with the space between valves, 4 and 10. The space back of valve, 1, is connected with the pilot valve chamber through the pipe connecting ports, 24 and 28.

This space is filled with water which is locked in by the pilot valves, 25, 12 and 26, so that, although the pressure acting to force 1 toward the back end of the cylinder is greater than the pressure acting to force 2 forward, 1 cannot move backward because the water back of it cannot escape. As the valves, 4 and 10, are of the same diameter, the pressure on them is balanced.

If it is desired to run the elevator up, the pilot valve lever, 29, is drawn upward. This movement carries 8 to the right and thus opens valve, 26, so that the water back of valve, 1, can escape through the pipe connecting with 24 into the lower chamber of the pilot valve, and through valve, 26, and valve, 19, to outlet port, 15, by the path indicated by arrow 20. Port, 15, is connected with the exhaust pipe so that the water has a free path from the back of 1 to the exhaust. The pressure on the front end of 1 being greater than that on the back of 2, the valves will be moved to the left and the supply chamber will be connected with the cylinder chamber as valve, 4, will uncover the ports connecting with the cylinder pipe.

The movement of the main valve to the left will carry lever, 11, upon which lever, 6, is fulcrumed at 7, in the same direction. The lever, 5, holds the lower end of 6 in position, so that the movement of 11 to the left moves 8 in the same direction. This movement of 8 continues until valve, 26, is returned to the position in which it is drawn, when the outlet for the water back of 1 is closed, and the movement of the main valve is arrested. If the lever, 29, is raised as far as it will go—or in other words, if the operator in the car throws the lever to the full speed position—the pilot valve, 26, will not be brought back to the position in which it is shown, by the movement of 11, until the main valve has moved to its extreme left position.

It will be noticed that when lever, 11, is moved to the left, by the movement of the main valve, and carries with it rod, 8, and pilot valves, it also carries to the right rod, 9, and the valves, 13 and 17, thus causing 13 to stop off the passage from valve, 23, to port, 14, by the path of arrow, 21. The object of this arrangement will be presently explained.

We have explained in the foregoing the movement of the valves when the elevator runs up, but we have not shown how to stop it. The upward movement of lever, 29, sets the car in motion on the descending trip, and to stop the car, the lever, 29, is moved downward. This downward movement of 29 carries 8 to the left and thus opens pilot valve, 25, thereby permitting water from the supply pipe to pass from inlet port, 14, through valves, 23, 22 and 25, to port, 24, and thus to the back end of main valve, 1. As water can now flow into the back end of the valve cylinder, 1 is forced to the right and thus valve, 4, covers the cylinder port and closes

the connection between the cylinder and the supply pipe, thus preventing further flow of water into the cylinder, and thereby stopping the movement of the plunger, and the car.

As can be readily seen, if the water can pass from inlet, 14, to the back of 1 fast enough, valve, 4, can be made to move so fast as to stop off the flow of water into the cylinder almost instantly. It can also be seen that, if the flow of water into the cylinder is stopped off too suddenly, the momentum of the plunger, the car, and other moving parts will carry them forward and cause the plunger to leave the surface of the water. As soon as the headway of the moving parts dies out, gravity will cause them to move back again and the plunger will strike the surface of the water and bring the car to a standstill with a violent jolt. It often happens that the car must be stopped as quickly as possible, and if the skill of the operator were depended upon to make the stop smoothly, he

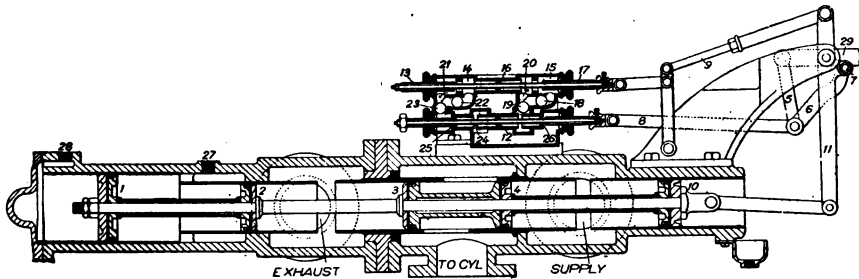


FIG. 77.

would be sure to miscalculate sometimes and move the operating lever too quickly. The valves, 17, 13, together with 23, 22 and 19, 18, are provided to make it impossible for the main valve to be closed too rapidly.

As will be seen, the valve, 13, is closed when the car is stopped on the up trip so that the water passing from 14 to 24 has to flow through the valves, 23, 22, and by properly adjusting 22 the flow of water into the main valve chamber back of 1 can be regulated so that valve, 4, will not close too rapidly. When this adjustment is made, all the operator in the car has to do, if he desires to stop as quickly as possible, is to throw the lever to the stop position instantly, and the water will flow through the valves in the pilot valve chamber at the highest permissible velocity but no faster.

If the car is running down, the movement of the main valve will be toward the right, and thus the rod, 9, will be moved to the left so that valve, 17, will be closed and the escape of water from the back of valve, 1, in stopping will be controlled by valve, 18.

Valves, 23 and 19, are not required to adjust the rapidity with which the main valve is closed in stopping, but for the purpose of controlling the rapidity with which the main valve is opened in starting. If an elevator runs at a very high velocity, it is possible for the valve to open so suddenly in making a start with a light load as to make the motion

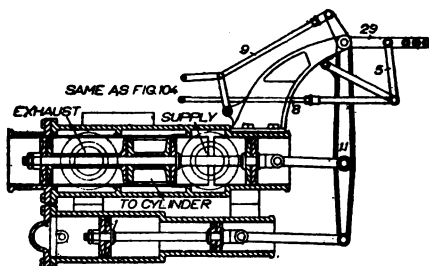


FIG. 78.

unpleasantly violent, but by properly adjusting the valves, 23 and 19, it becomes impossible to make a too sudden start.

Fig. 78 shows a modified arrangement of the valves. The pilot valves are the same as in Fig. 77 but the main valve is arranged with the cylinder divided into two sections of less length, the large, or actuating

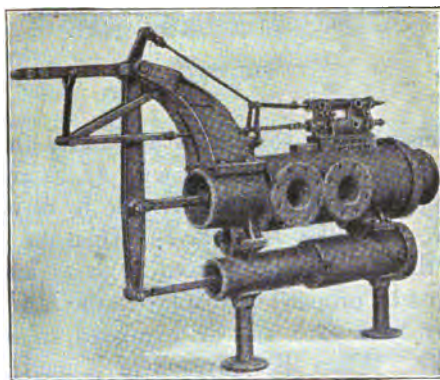


FIG. 79.

valve, 1, being placed in the lower cylinder. The action of this valve is the same as that of Fig. 77 so that an extended explanation is unnecessary.

The half-tone Fig. 79 will serve to make clearer the construction of Fig. 78.

Fig. 80 is a plan and sectional view of another design of operating valve made by the Plunger Elevator Co. The difference in the main valve is that the piping shown in Fig. 76 to connect the several parts is

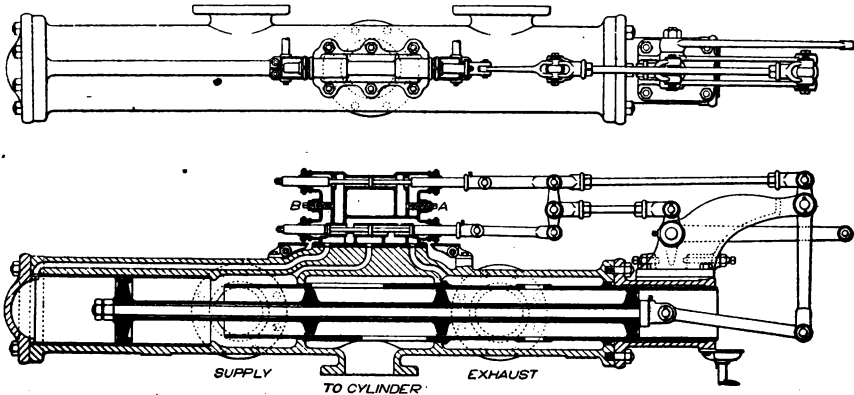


FIG. 80.

dispensed with and the cylinder is cast with the necessary passages to make the required connections. The pilot valves are modified by dis-

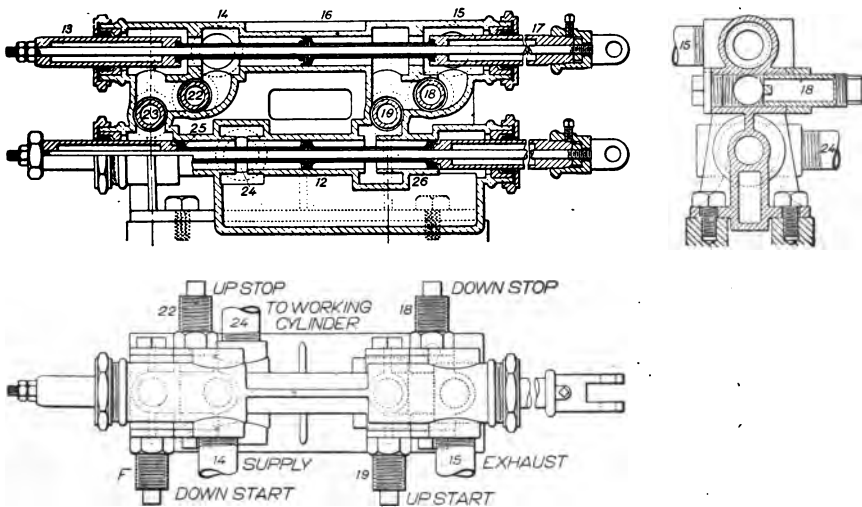


FIG. 81.

pensing with the adjusting valves, 22, 23 and 18, 19, Fig. 77, and substituting for them the screws, A and B, Fig. 80.

As explained in connection with Fig. 77, the valves, 23 and 19, are

used to adjust the rapidity with which the main valve opens in starting and stopping the elevator, so as to avoid a too rapid movement in the car. This adjustment is not necessary with elevators that run at the velocity usually employed; in fact experience shows that in such cases it is practically impossible to make a too violent start, and on that account these valves are not used except in cases where the car speed is unusually high.

The screw valves, *A* and *B*, in Fig. 80, serve the same purpose as 22 and 18 in Fig. 77, that is, they are used to adjust the rapidity of closing off the main valve in stopping.

The type of pilot valves shown in Fig. 77 can be better understood by reference to Fig. 81, which is drawn to a larger scale, and shows sectional views of the valve and a top view looking down upon it. From the cross sections, it will be seen that the valves, 22 and 18, are simply screws that are run in as far as may be necessary to check the flow of water to the proper point when the valve, 13 or 17, is closed. The passages through the chamber of these pilot valves are of such form that it is not easy to show them in a clear manner in the drawings, but by studying Fig. 81 they can be readily traced out. The valves, 23 and 19, are of the same form as 22 and 18 and are similarly arranged.

## CHAPTER XII.

## THE AERO-HYDRAULIC ELEVATOR.

THIS is a system in which the water pressure required to operate the car is obtained by means of compressed air, or steam, which is admitted to the top of a pressure tank in which the water is contained. The system is not economical in operation, in fact it requires more energy than any other hydraulic elevator used, to perform a given amount of work; but as an offset to its inefficiency it possesses the advantage of being very compact and inexpensive to install.

Aero-hydraulic elevators are used quite extensively in Paris, France, where compressed air is supplied from a central station, through a system of street mains. In this country these elevators are used in places where there is an abundant supply of compressed air, or steam which is not used in any other way, or where fuel is so cheap as to make its cost a matter of secondary consideration.

The general arrangement of the aero-hydraulic system is well shown in Fig. 82, although the valves depicted in this illustration are not at all like those in an actual installation. The actual construction of the valves and other parts is shown clearly in the other drawings that accompany this article.

The operation of the aero-hydraulic system as shown in Fig. 82 is very simple. Compressed air enters through the supply pipe and passes to the top of the pressure tank, forcing the water out through the pressure pipe into the upper end of the hydraulic lifting cylinder, thus forcing the piston downward. The traveling sheaves attached to the upper ends of the piston rods draw down the elevator lifting ropes and thereby cause the car to ascend, in the manner fully explained in the previous articles of this series. The hydraulic lifting cylinder shown in this drawing is of the vertical type, but a horizontal cylinder, or a plunger machine can be used with equal success.

For the purpose of maintaining an equal pressure upon the piston, the open tank and the discharge pipe that connects it with the lower end of the lifting cylinder are provided and these would not be required, if the lifting cylinder were of the horizontal type. The explanation of the way in which the tank and discharge pipe act to keep the pressure on the piston of the lifting cylinder uniform is as follows: When the piston is at the top of the lifting cylinder, the water from the open tank flows into the cylinder and fills the latter up to the under side of the piston. As the open tank is located on a level with the upper end of the lifting cylinder, the water in the discharge pipe balances that which fills the

lower end of the cylinder, so that the only pressure acting to force the piston downward is that due to the air in the pressure tank. When the piston is at the bottom of the lifting cylinder, it is still forced

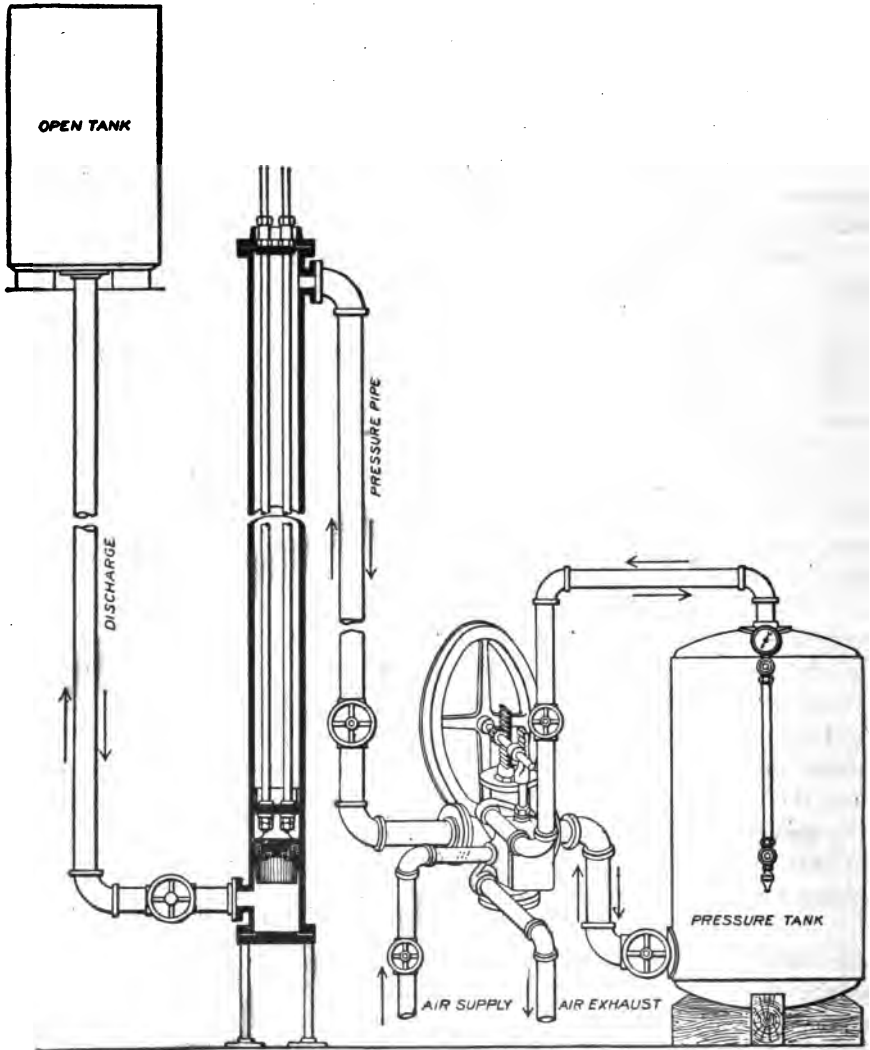


FIG. 82.

downward by the pressure from the pressure tank only, because the water in the cylinder above the piston is balanced by the water in the discharge pipe.

If the discharge pipe and open tank were not used, the pressure on the piston would be greater at the bottom than at the top because in the latter position it would be simply the pressure of the pressure tank, while in the former position it would be the pressure of the pressure tank plus the weight of the water in the cylinder above the piston. With a horizontal lifting cylinder the open tank and discharge pipe would not be required because the piston would move in a horizontal direction, and therefore, no pressure would be added by the weight of the water in the cylinder.

The valves by means of which the movement of the piston in the lifting cylinder is controlled are actuated by the rotation of the operating sheaves, mounted on the end of the valve-actuating shaft. This sheave is rotated by means of the ordinary hand rope that passes through the elevator car. When the sheave is turned in a clockwise direction the car ascends, and when turned in the opposite direction the car descends. When the sheave is returned to the central position, the car stops.

When the sheave is turned clockwise, to make the car ascend, the compressed air supply pipe is connected with the pipe leading to the upper end of the pressure tank, and thus the pressure of the air is impressed upon the upper surface of the water. At the same time the water valve is opened so as to connect the lower end of the pressure tank with the pressure pipe through which water passes to the upper end of the lifting cylinder. So long as the valves remain open in the position just explained, water will flow into the upper end of the lifting cylinder, and the piston will move downward and the car will ascend.

When it is desired to stop the car, the operating sheave is rotated back to the stop position, and then the air and water valves are closed, so that no more air can pass into the pressure tank, and no more water can flow out of it into the lifting cylinder.

To run the car downward, the operating sheave is rotated counter clockwise, which lifts the air valve so as to connect the upper end of the pressure tank with the air exhaust pipe, thus permitting the air in the tank to escape and relieve the pressure. This movement of the operating sheave also opens the water valve so as to connect the top of the lifting cylinder with the lower end of the pressure tank, and as the air pressure in the latter is removed, the weight of the elevator car is able to lift the piston in the lifting cylinder and thus force the water back into the pressure tank.

From the foregoing, it will be seen that in making an up trip of the car, compressed air rushes into the top of the pressure tank, so as to force the water out into the lifting cylinder, and that when the descending trip is made, the compressed air in the tank escapes through the exhaust

pipe, while the water in the lifting cylinder returns to the pressure tank. The efficiency of operation of the system, when compressed air is used, is the same as that which would be obtained, if the air were used to operate a pump to force water into the pressure tank, provided that the pump did not use the air expansively. In fact it would be a trifle higher than would be obtained with such a pumping system, because the frictional loss would be less. If steam is used to force the water out of the pressure tank, the efficiency will be considerably lower than with compressed air owing to the condensation of the steam that comes in contact with the

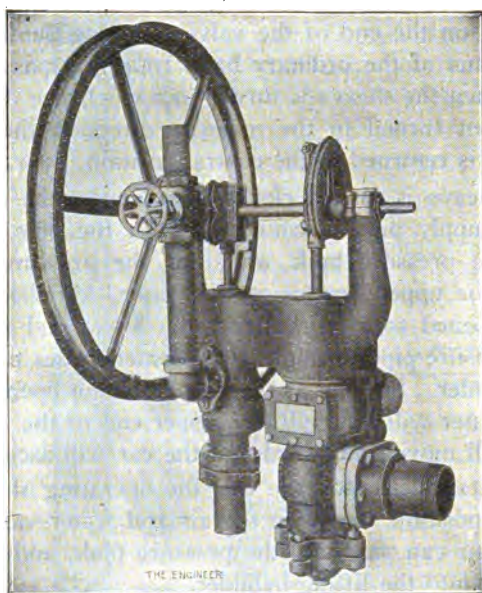


FIG. 83.

upper surface of the water. The loss by condensation, however, is not as great as might be supposed because, as the same water is used over and over, it soon becomes heated to such a temperature as to make the condensation slight.

When compressed air is used, the water in the pressure tank has to be replenished from time to time to make up for the inevitable loss through leakage, but when steam is used, water has to be drawn from the tank occasionally as the condensation of the steam gradually increases the amount.

The air valve cylinder is cast integral with the frame that supports

the operating sheave shaft and the arrangement of the ports is as shown in Fig. 89, which is a vertical section, end view.

A half-tone of the valves is shown in Fig. 83, and this is the design

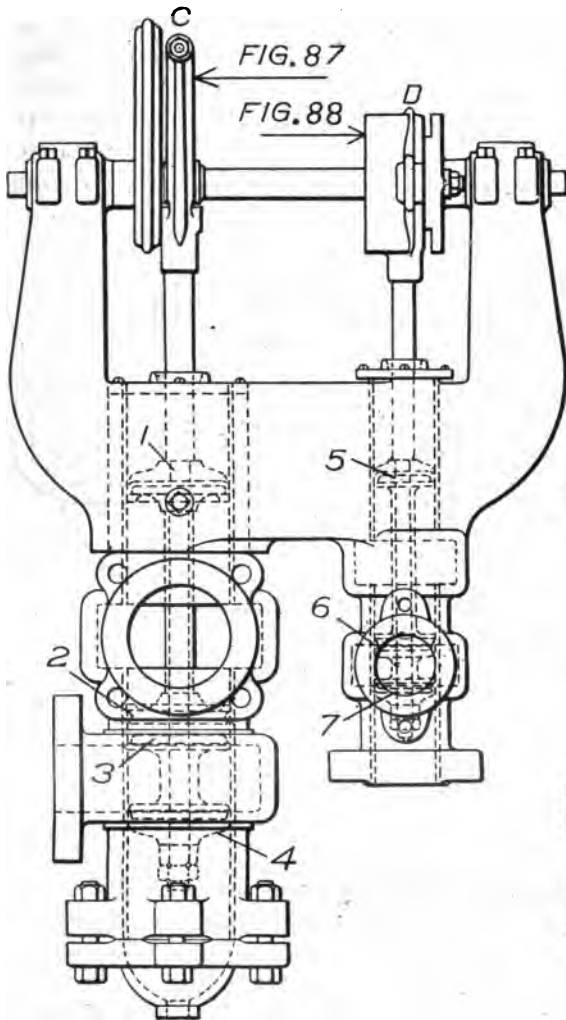


FIG. 84.

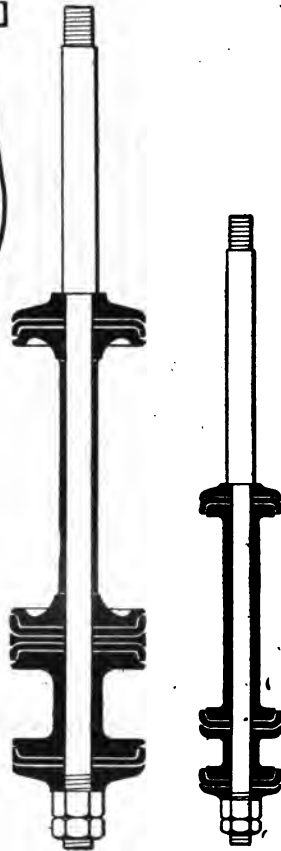


FIG. 85. FIG. 86.

of valves actually used; the internal construction can be clearly understood from the line drawings, Fig. 84, and the various details shown in Figs. 85 to 87.

Fig. 84 shows the valves in front and side elevation. The valves

are shown in dotted lines, their actual construction being more clearly shown in Figs. 85 and 86, the first is the water valve, and the second the air valve. The valves are moved by means of cams which are of such form that the water valve is moved downward, whichever way the operating sheave shaft, *F*, is turned, while the air valve is moved up by rotation of the shaft in one direction, and down, by rotation in the opposite direction. The cam, *C*, actuates the water valve, and *D* actuates the air valve. Front views of these cams are given in Figs. 87 and 88. From Fig. 87 it will be seen that if the shaft, *F*, is rotated clockwise, the roller, *C'*, will travel along the curve, *M*, and

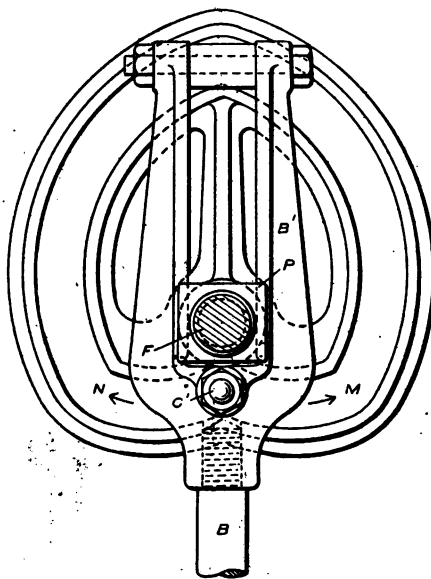


FIG. 87.

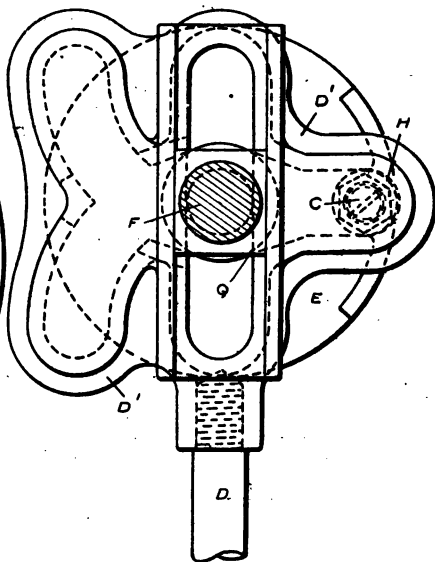


FIG. 88.

if *F* is rotated anticlockwise, *C'* will travel along the curve, *N*, and in either case, *C'* will move away from *F*. The guide block, *P*, is mounted on shaft, *F*, and serves to guide the frame, *B'*, to which roller, *C'*, is attached, so that as *C'* moves away from *F* it must move downward.

In Fig. 88, which shows the air valve cam, the roller, *C*, is mounted upon the disk, *E*, which is secured to shaft, *F*, and rotates with it. The cam proper is attached to the upper end of the valve rod, *D*, and is marked *D'*. The guide block, *Q*, slides in a vertical slot in *D'*. In this arrangement it will be seen that if *E* is rotated clockwise, the roller, *C*, will move downward carrying *D'* with it, while if *E* is rotated in the opposite direction, *C* will move upward carrying *D'* in the same direction.

From Fig. 84, it will be seen that to admit water into the lifting cylinder, the water valve must be moved downward, so that valve piston 2 may pass below the port that connects with the cylinder. It will also be seen that the valve must move in the same direction to permit water to flow back from the cylinder to the pressure tank. Looking at the air

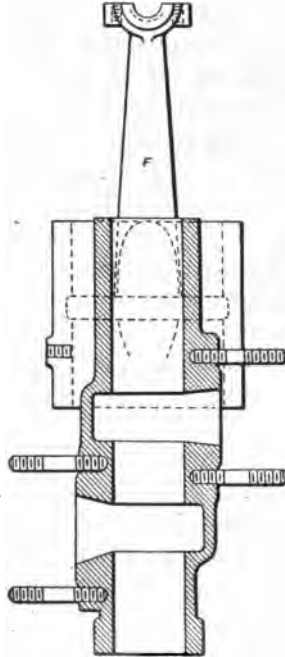


FIG. 89.

valve it will be noticed that to admit compressed air into the pressure tank the valve must be moved down so as to connect the air supply port with the water tank port. To withdraw the compressed air from the tank the valve must be lifted so as to connect the water tank port with the exhaust.

## CHAPTER XIII.

## ELEVATOR SAFETY APPLIANCES, WEDGE TYPE.

WHEN elevators first came into use, the car was lifted by means of a single rope. As it was evident that this rope might, under certain conditions, break and allow the car to drop to the bottom of the well, means were devised to catch the car, if such an accident should occur. The means employed consisted of iron racks placed on either side of the elevator well, and suitable dogs located where they could catch in the teeth of the rack if the rope broke. The racks also acted as guides for the car. The dogs were held out of engagement with the racks by being connected through levers with the lifting rope. When the rope broke, strong springs would force the dogs out so as to catch the racks.

This type of safety is to be found, even at the present day, on many freight elevators, but for passenger service it is entirely out of date. At first glance the device would appear to be effective, but experience has shown that the dogs can fail to catch the teeth of the racks, or, if they do catch, they can strip the teeth and thus fail to hold the car. When they succeed in holding the car, the movement of the latter is stopped so suddenly that, if the velocity it has acquired is sufficiently high, the effect upon passengers or freight is nearly as serious as if the car went to the bottom of the elevator shaft.

Early in the history of elevators, the danger of dropping the car was considerably reduced by using two or more lifting ropes. When this improvement was made, elevators were supposed by many to be perfectly safe, and that impression prevails to a great extent even now, although, as a matter of fact, the multiplicity of lifting ropes is only a partial safeguard. The use of a number of lifting ropes is commonly regarded as a perfect safeguard, because it is self-evident that for all the ropes to break at the same time is practically impossible, provided each rope is strong enough to carry the load alone, which is always the case. A little reflection, however, will show that, even if the ropes do not give way, it is possible for some part of the hoisting mechanism to break or get out of adjustment and thereby allow the car to descend at a speed nearly as great as it would attain, if the lifting ropes parted.

When an elevator car attains a dangerously high speed, while the lifting ropes remain intact, it is said to run away, and all the most approved modern safety devices provide means for stopping the car when

the velocity passes the safe limit, regardless of the nature of the disarrangement that causes the high velocity.

One successful form of safety device, which is used by the Otis Elevator Co., in small buildings or where the insurance regulations permit the use of wooden guides, is shown in Figs. 90, 91 and 92. This device, which is called a safety plank, is placed under the car, and serves also as a guide for the lower end of the latter. Fig. 90 is an end view of the safety plank, Fig. 91 is a side view, and Fig. 92 is a view looking upward at the under side. In the last named figure, *M* is a section through the hardwood guide secured to the side of the elevator well, and upon which the car slides. The three figures show one end of the

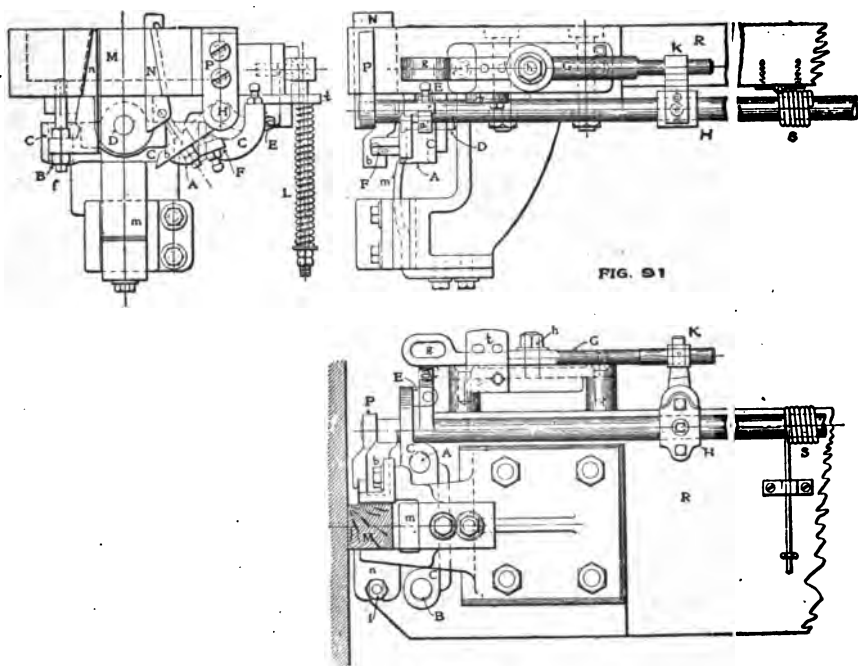


FIG. 90. FIG. 91. FIG. 92.

safety plank only, the other end being a duplicate of it. The car is lifted by means of four ropes, two of which are secured in the ends, *AB*, of a rock beam, *C*, the other two being fastened in like manner to a similar beam at the other end of the plank. The beam, *C*, swings freely around the stud, *D*, hence, if one of the ropes should break, the end of *C* to which it is secured would drop. The shaft, *H*, carries a lever, *b*, at its outer end and another lever, *a*. The rock beam, *C*, has projections, *E*

and *F*, provided with adjusting screws, which are in the paths of levers, *b* and *a*. If the end, *B*, of *C* drops, the projection, *F*, will force lever, *b*, upward, and if the opposite end of *C* drops, projection, *E*, will force *a* downward, and thus rotate shaft, *H*, and thereby lift *b*. When *b* is lifted, it strikes the wedge, *N*, and forces it tightly against the guide, *M*, thereby arresting the downward motion of the elevator car. The end of *b* also cuts into the side of *M*, so that if the frictional resistance developed by the binding of wedge, *N*, against *M* is not sufficient to stop the car, descent is prevented by the embedding of *b* in the side of *M*.

From the foregoing, it will be seen that, if any one of the four lifting ropes breaks, the wedge, *N*, will be thrown into action and stop the car. As stated above, however, the car can attain a dangerous velocity without breaking any of the ropes, and for complete protection it is necessary to provide means for stopping the car in such cases. The lever, *G*, shown in Figs. 91 and 92 swings around the stud, *h*, and the end toward the right moves an arm, *k*, that is mounted upon shaft, *H*. The end, *g*, of this lever is fastened to a rope that runs over a sheave at the top of the elevator well and drives a governor, and under another sheave at the bottom of the well.

When the elevator car is running at normal velocity, this rope moves freely and the spring, *S*, is able to hold shaft, *H*, from rotating. If the car attains a dangerous velocity, the governor at the top of the well will move far enough to bring a clamping device into action that will bind the rope and thus draw up the end, *g*, of lever, *G*, and thereby rotate shaft, *H*, and raise lever, *b*, against wedge, *N*, and throw the latter into action.

Spring, *L*, which is shown in Fig. 90 only, acts in conjunction with *S* to hold *G* and *H* in the normal position. The various parts of the apparatus are secured to a massive hardwood plank, *R*, which is made from 10 to 14 inches wide and from 4 to 6 inches thick, according to the size of the car. The hardwood plank, *R*, is replaced in some cases by an iron framing.

It will be noticed that the wedge, *N*, is held down by means of a bolt that passes through lever, *b*. This construction is necessary, as the wedge acts as one side of the guide for the lower end of the car, hence, if not held down, it would be liable to become wedged when the elevator is in perfect running order, although, in the design shown, the lower end of the car is guided in part by the casting that holds spring, *m*, the latter acting to prevent side sway of the car. By means of the stationary wedge, *n*, shown in Fig. 90 and the loose side of the lower guide the slack on the sides of *M* can be taken up. In other designs, this adjustment is effected entirely by the set of the stationary wedge.

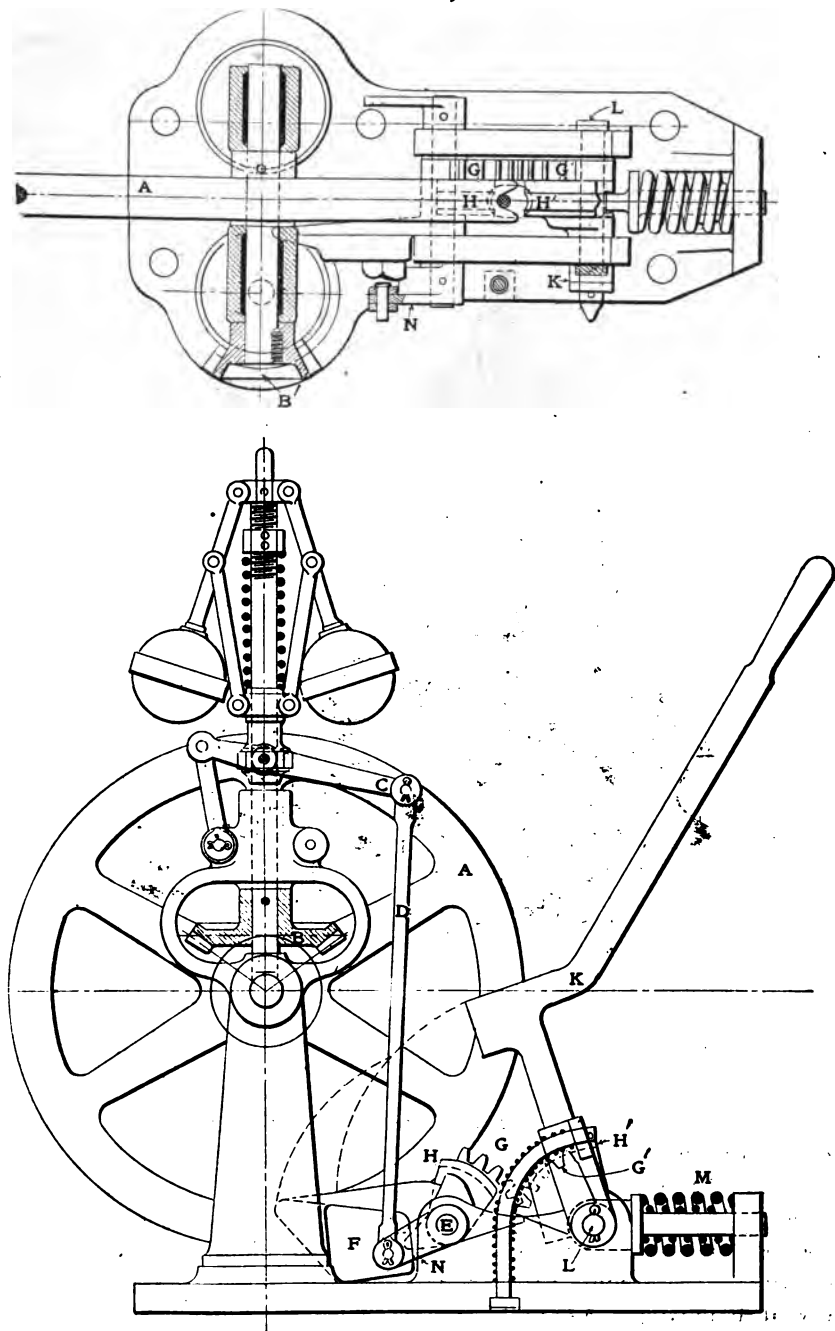


FIG. 93.

In connection with the safety planks described in the foregoing the type of governor shown in Fig. 93 is used, a vertical elevation and a plan being shown. The rope that is fastened to the end, *g*, of the lever, *G*, on the safety plank passes around the sheave, *A*, and drives the governor. When the governor balls swing outward, the lever, *C*, is raised and through the connecting rod, *D*, and crank, *N*, rotates the shaft, *E*. This shaft carries a toothed segment, *G*, which meshes into another segment,

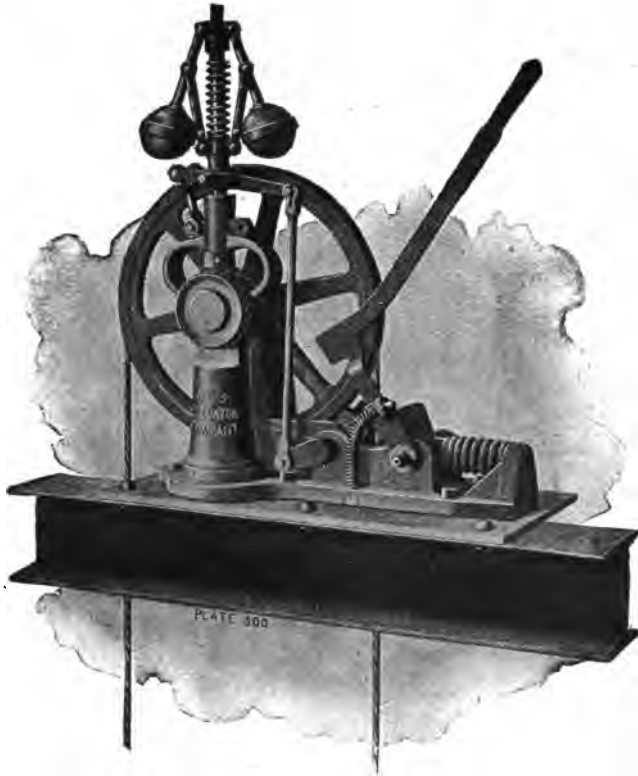


FIG. 94.

*G'*. Both these segments carry at one side grooved surfaces, *H H'*, the position of which is well shown in Fig. 94.

These grooved surfaces are eccentric to the shafts, *E* and *L*, and as *E* rotates in a clockwise direction, *H* and *H'* come nearer together. The rope that passes over sheave, *A*, runs between the grooves on *H* and *H'*, and when these come near enough together, they clamp the rope and prevent its moving. As will be seen at once, the distance between *H* and *H'* will decrease as *E* rotates, and the rotation of *E* will increase as the

balls of the governor spread out, or, in other words, as the speed of the rope that drives *A* increases; hence, by properly adjusting the governor spring, the clamps *HH'* can be made to grip the rope at any desired velocity.

When the governor moves far enough to cause the clamps, *HH'*, to bind the rope, the spring, *M*, permits the shaft, *L*, to move backward and thus regulate the pressure with which the rope is clamped. The spring on the curved rod in front of *G* acts to throw the clamps upward

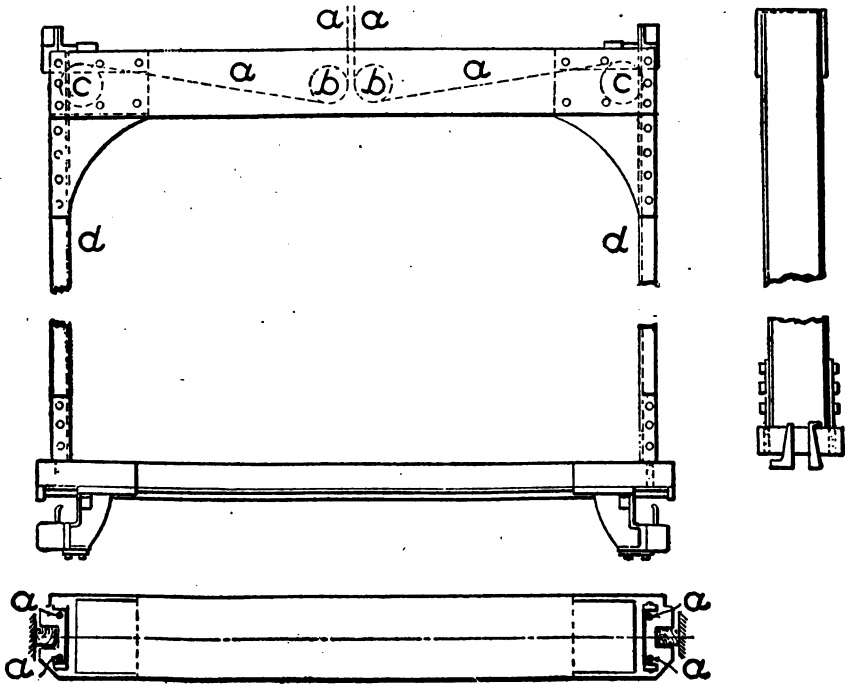


FIG. 95.

when the rope is released after the governor has acted, but, if the elevator is running with a very heavy load at the time, *G* and *G'* may swing so far around that they will not move back to the normal position by the action of this spring alone; hence the hand lever, *K*, is provided so that the clamps may be drawn out of the way without difficulty.

The position of the safety plank under the elevator car, and also the way in which the lifting ropes are led to and connected with it can be easily understood from Fig. 95, which is three views of the frame that carries the car proper. The lifting ropes, *a a*, pass under small sheaves

or blocks, *b b*, held in the center of the top cross beam and over similar supports at the sides; thence down within the channel bars, *d d*, in the positions shown in the plan. The side view shows the end of the safety plank with the wedges outlined in their proper position. The top car guides are shown mounted upon the top cross beam.

In these illustrations four lifting ropes are shown, but, in addition, there are generally two more that pass over a sheave at the top of the elevator well and run down to a counterbalance weight. These counterbalance ropes are not connected with the safety plank, but terminate at the cross beam.

With freight elevators, as a rule, there are two lifting ropes that are connected with the safety plank and two counterbalance ropes. When only two lifting ropes are used the safety plank is modified so that when a rope breaks a spring throws the end of the rock beam, *C*, upward. The action of the governor is the same as with the four-rope safety.

## CHAPTER XIV.

## ELEVATOR SAFETY APPLIANCES, GRIP TYPE.

**I**N THE last chapter what is known as the wedge safety was described. In this device, the motion of the car is arrested by throwing in a wedge between the vertical stationary guides upon which the car slides and the jaws of a massive safety plank attached to the under side of the car floor. In-so-far as arresting the motion of the car is concerned, the wedge safety is perfect if properly designed—that is, if the wedge is given the proper taper.

Friction of one side of the wedge against the side of the stationary guide tends to hold it motionless, and thus to draw it further into the space between the jaw of the safety plank and the side of the guide. Movement of the wedge into this space is opposed, however, by the friction between its outer side and the side of the jaw of the safety plank; therefore, if the taper of the wedge is too blunt, the friction between it and the side of the jaw will be so much in excess of that between it and the side of the stationary guide, that it will not be drawn into the space sufficiently far to develop as great a frictional resistance against the side of the stationary guide as is required to hold the car.

If the wedge is made too sharp, it may be drawn in so tight when called into action as to break the jaws of the safety plank, and thereby render the device useless. Experimentally, the proper taper to give to the wedge can be accurately ascertained, and it is in this manner that the form given has been determined upon.

One objection to safeties of the wedge type, which makes them undesirable for high-speed elevators, is that, while they may stop a car in a distance of 2 or 3 feet, they may also stop it in a few inches. If a car is descending at a high velocity and its movement is arrested in 6 inches, the shock experienced by the passengers is liable to be serious. Elevator cars do not usually drop by the breaking of the lifting ropes, but run away through some disarrangement of the hoisting mechanism. The safety governor is provided to throw the safety device on the car into action whenever the speed exceeds a predetermined amount. If a car is arranged to run normally at a maximum velocity of 250 feet a minute, the safety governor can be set so as to throw the car safeties into action at a speed of 450 or 500 feet a minute. If a car is descending at the last-named velocity and the safety wedges are thrown into action, and arrest the motion within a distance of 5 or 6 inches, the shock upon the passengers will not be very severe, probably not any more than

enough to give them a bad shaking up. If, however, the car runs at a maximum normal velocity of 450 to 500 feet a minute, the safety governor will have to be set so as to act at a correspondingly higher velocity, say at 800 feet, and if when running at this speed the motion is arrested within 6 inches, the shock upon the passengers will be far greater than at the lower velocity.

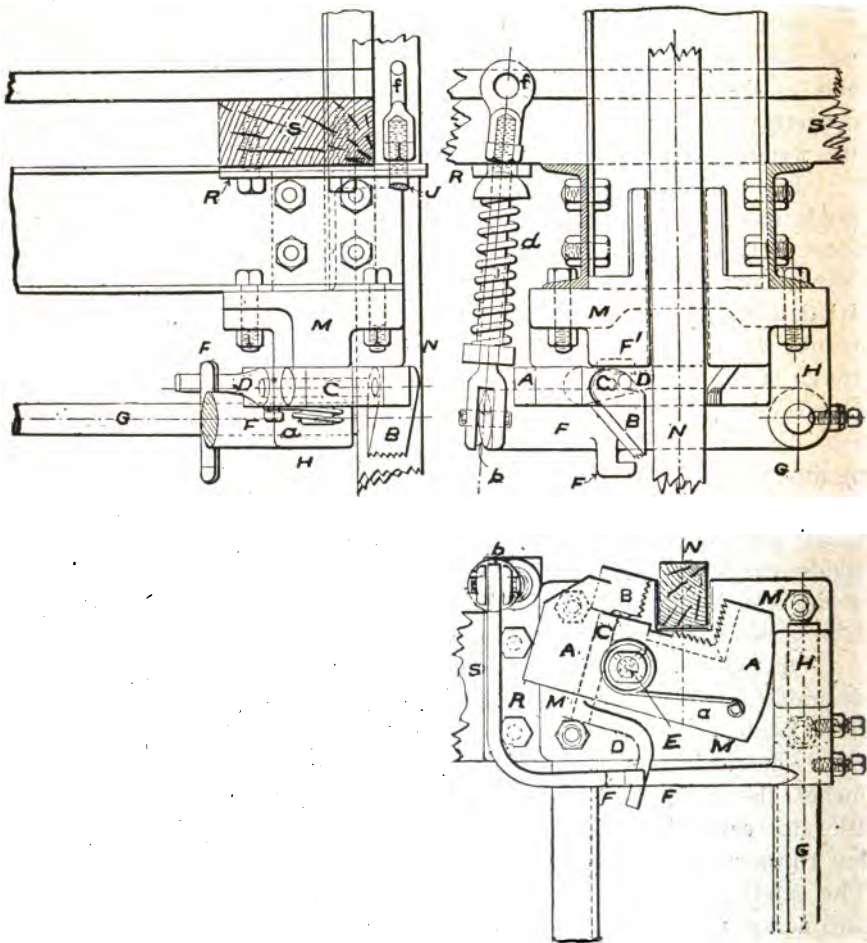


FIG. 96. FIG. 97. FIG. 98.

Some form of safety device that will stop a runaway car gradually has been rendered necessary by the advent of high-speed elevators in modern office buildings. Safety devices of this type, to be satisfactory, must act in such a manner as to make it certain that, under all conditions,

they will produce a gradual retardation of the velocity. An efficient safety of this type, which is called the "triple grip safety," is shown in Figs. 96, 97 and 98. Fig. 96 is a vertical elevation of the bottom of an elevator car showing the safety plank in position, giving a side view of the latter. Fig. 98 is a view of the under side of the safety plank, and Fig. 97 is an end view of the same. The stationary guides upon which the car slides are shown at *N* and are made of hardwood. The casting, *M*, which is bolted to the under side of the channel beams that form the safety plank serves as a guide for the lower end of the car, as well as a supporting frame for the movable parts of the safety device.

In Fig. 98 it will be noticed that the piece, *A*, which swings around the stud, *E*, has two sets of saw teeth so disposed that they will press against two sides of the guide, *N*, when *A* is swung far enough around the stud, *E*. The shaft, *C*, which passes through *A*, carries a lever, *B*, at one end and another lever, *D*, at the opposite end. The lever, *B*, is provided with saw teeth on its end, and although in Fig. 98 it appears to be quite short, it is rather long, as is more clearly shown in the other two views. The side of *B* next to the guide, *N*, is parallel with the latter. The lever, *D*, rests on top of lever, *F*, which is fastened to the shaft, *G*. This shaft, *G*, runs from one side of the car to the other, and has a lever at the opposite end that runs under another *D* lever. The extreme end, *b*, of lever, *F*, is secured to one end of the rope that is actuated by the safety governor, as shown in Fig. 97, the attachment to the rope being effected through the rod, *J*. The governor rope is fastened to the eye, *f*, in the upper end of *J*. The spring, *d*, which presses against the guide, *R*, acts to hold *J* in the position in which it is drawn, when the car is running at normal speed.

If the car for any reason attains a velocity great enough to cause the safety governor to act, the rod, *J*, is pulled up and carries with it the lever, *F*. The upward movement of *F* swings lever, *D*, around, and this rotation causes the toothed end of *B* to press against guide, *N*, and at the same time the piece, *A*, swings around stud, *E*, so as to bring its two toothed edges against the other two sides of *N*. In this way it will be seen that the three rows of saw teeth are caused to press against the sides of the guide, *N*. The parts *A* and *B* are made with sharp cutting edges where the teeth are shown, and as soon as they come into contact with the guide, *N*, they shave down its sides, and the force required to do this shaving arrests the movement of the elevator car.

As the lever, *F*, is secured to shaft, *G*, the latter is rotated and the jaws are thrown into action at the opposite end of the safety plank. The flat side of *B*, facing guide, *N*, prevents the teeth from cutting too deeply into the wood and thus bringing the car to a sudden stop. This action is

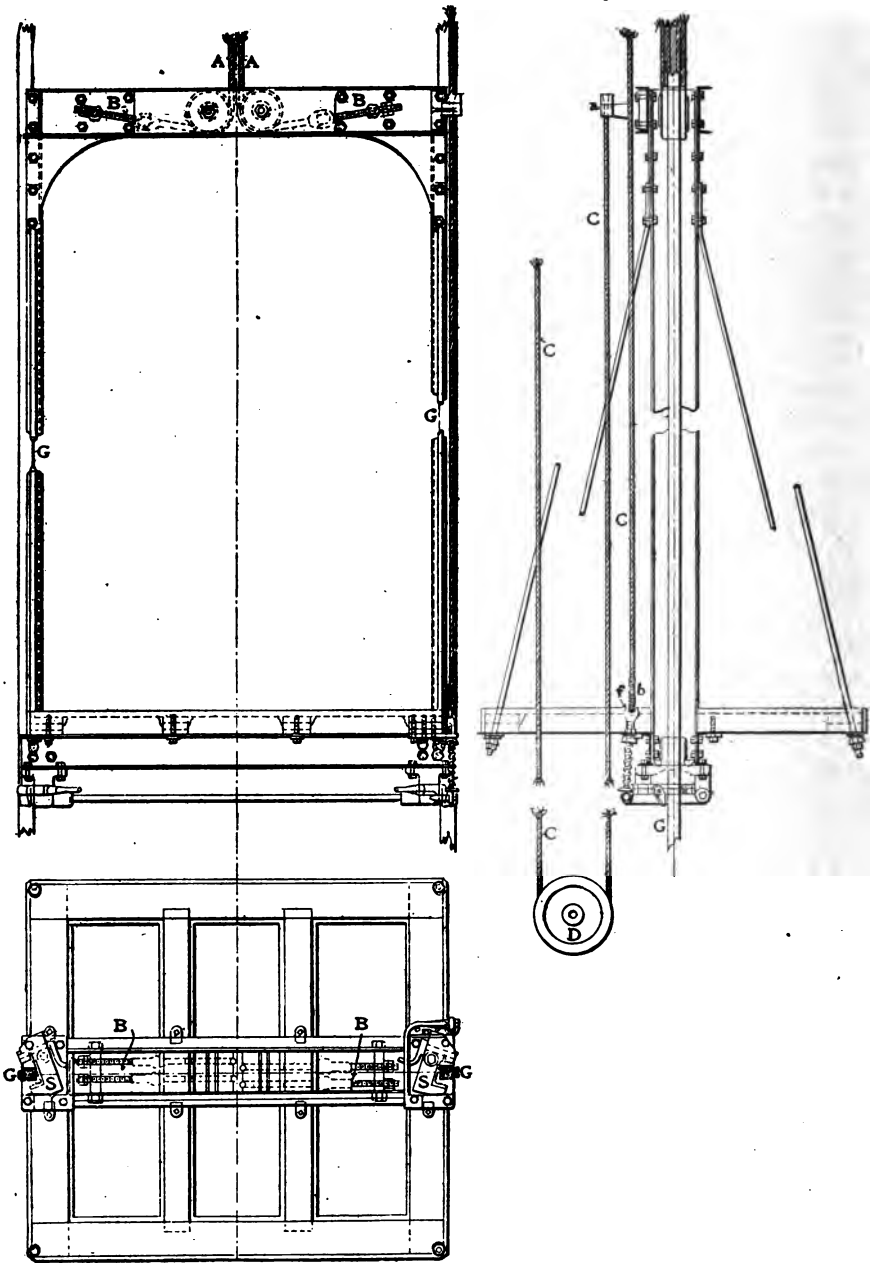


FIG. 99.

further prevented by the projection,  $F'$ , on lever,  $F$ , which holds the end of  $D$  so that it can only swing around as far as the movement of  $F$  will permit.

From the foregoing description, it will be seen that the momentum of the car is expended in removing shavings from the three sides of the hardwood guide,  $N$ . The retarding effect obtained in this way cannot arrest the motion of the car instantly, but to some it may appear that the force required to shave down the guide sides is entirely too small to hold the weight of a heavy elevator car. As a matter of fact, however, the effort required to shave the sides of a guide 3 inches square is sufficient to bring a car of large size fully loaded to a state of rest in as short a distance as is desirable.

Between this safety and the wedge safety an important difference is that, while the latter is arranged so as to act whenever a lifting rope breaks, in the present device no such provision is made; it is dependent entirely upon the action of the safety governor. When it is considered that the breaking of one or even two of the lifting ropes will not permit the car to drop, it can be seen that it is wholly unnecessary to arrange the safety so as to be actuated when a rope gives away. The only possible advantage from making a safety to act in this way is, that, if a rope breaks and the car continues to run, the loose end of the broken rope may become tangled with the remaining ropes and possibly throw them off the overhead sheaves, and thus get the apparatus into such a disordered condition that it would require a considerable amount of time and expense to repair the damage.

From Fig. 99 the way in which the car is suspended from the lifting ropes and the manner in which the safety is connected with the governor rope can be seen. Fig. 99 shows a front vertical elevation of an elevator platform, a side elevation, and the under side of the platform. The lifting ropes,  $AA$ , are secured to the cross beam at the points  $BB$ . The stationary guides upon which the car slides are shown at  $GG$ . The lower end of the car is guided by the castings attached to the ends of the safety plank, and the upper end is guided by jaws secured to the ends of the top cross beam.

Governor rope,  $CC$ , has one end secured to the top cross beam at  $a$ , and the other end,  $b$ , is fastened to the rod,  $f$ . Starting from the end,  $a$ , the rope runs down to the bottom of the elevator well and under a weighted sheave,  $D$ ; thence, upward to the top of the well and around the sheave of the governor, and then down again to the top of rod,  $f$ . The end of the rope that is attached to the top of rod,  $f$ , passes through the clamps of the governor; hence, when the latter closes the clamps

sufficiently tight to grip the rope,  $f$  is raised and the safety grips the guides,  $G$ .

For the weighted sheave wheel,  $D$ , the construction is shown in Fig. 100. The weight,  $B$ , is made sufficient to give the rope,  $C$ , the proper tension, and, as it slides freely on the guides,  $E E$ , the tension is not affected by expansion or stretching of the rope. The frame in which  $B$  slides is firmly bolted to the side of the pit at the bottom of the elevator shaft.

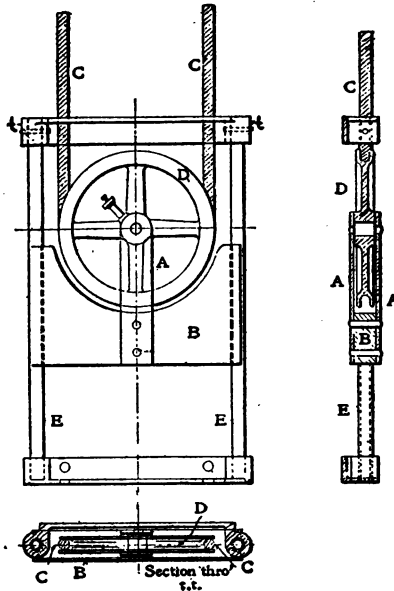


FIG. 100.

That this type of safety destroys a portion of the guides every time it comes into action, may be looked upon as an objection, but in reality it is not, as in this respect it is no worse than the wedge safety, which also destroys the guide whenever it is called into action. If these devices acted every day or two, the destruction of the guides might be regarded as a rather serious matter, but as under actual practical conditions, they are not likely to be called upon more than once or twice in a lifetime, it matters little whether they rip the guides into splinters or not so long as they stop the car, yet do not stop it so suddenly as to injure the passengers.

## CHAPTER XV.

## ELEVATOR SAFETY APPLIANCES FOR IRON GUIDES.

**I**N THE two preceding chapters, safety appliances are described that are used in connection with elevators running on hardwood guides. Such guides are found in practice to be fully as efficient as those made of iron, but in large office buildings where a construction is desired that is as nearly fireproof as it can be made, no wood can be used in the

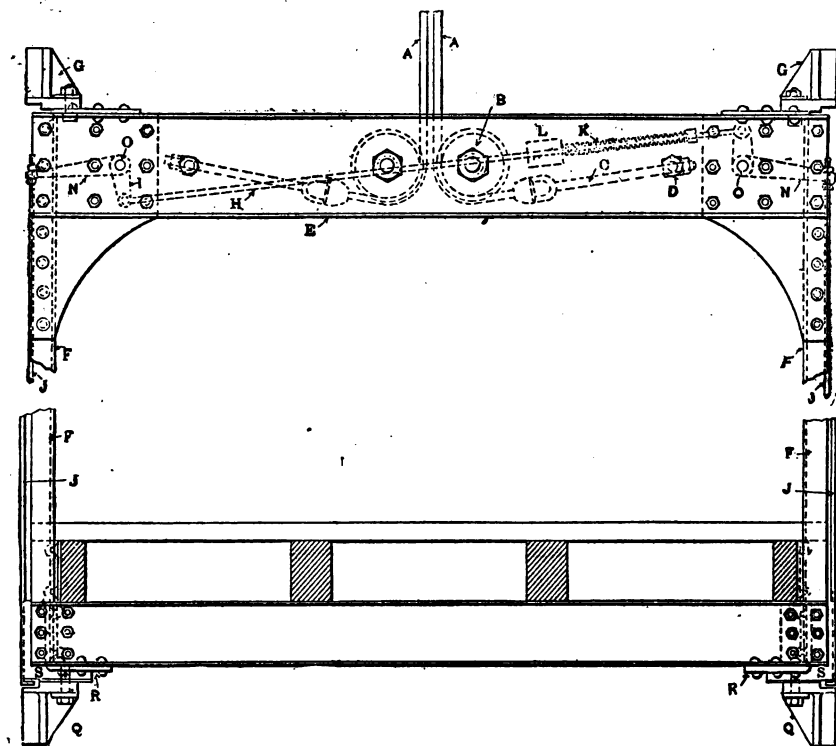


FIG. 101.

construction of any part of the elevator well; hence, in all such buildings, iron guides are used. These guides are made almost exclusively of T-bars, which vary in size from about 3-inch flange and 2-inch stem to 4-inch flange and 3-inch stem. The flange of the bar is firmly secured to the side of the elevator well, and the stem forms the guide.

With these iron guides, several forms of safety grips are used, some

of which act upon the principle of the wedge device, and others on the principle of an ordinary brake, the actuating apparatus being arranged so as to increase the pressure continuously from the instant when the brake begins to act, until it stops the motion of the car.

Figs. 101 to 103 show a safety which is known as the roll type, and is a modification of the wedge device, the difference being that a steel roller is substituted for the wedge.

Fig. 101 shows the crosshead or top of the frame that supports the elevator car, and the lower portion shows the floor and the safety plank

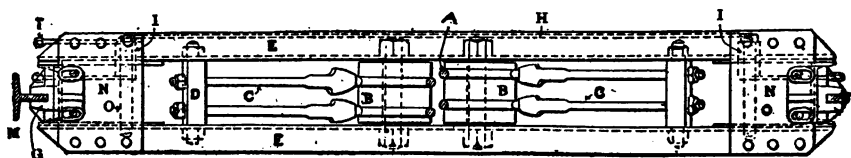


FIG. 102.

under it. This safety is arranged so as to be actuated by the increased velocity of the car, exclusively. The lifting ropes, *A A*, pass under cylindrical bearings, *B B*, and are secured to the ends of bolts, *C*, which latter are held by bars, *D*, fastened to the sides, *E E*, of the crosshead. The construction is fully shown in Fig. 102. The T-iron guides are shown at *M*, and the car is guided by means of shoes, *G* and *Q*, Fig. 101, made of cast iron and mounted on top of the crosshead and under the safety plank.

To insure smooth running of the car the guides, *M*, are planed off as far back from the edge as the shoes, *G* and *Q*, reach, and the latter

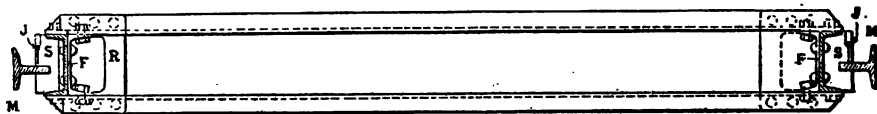


FIG. 103.

are made so as to be a free fit. The guides, *M*, are not, however, planed in all cases.

At each end of the crosshead a rocker shaft, *O*, is placed which carries crank levers, *I* and *N*. The levers, *I*, on the two shafts, are connected with each other by means of a rod, *H*. The ends of the levers, *N N*, support the upper ends of the side rods, *J*, that run down to the bottom of the safety plank where they terminate in hooked ends, the hooks turning inward. One of the shafts, *O*, carries an additional lever, *T*, as is shown in Fig. 102.

If the outer end of *T* is lifted, the ends of the two *N* levers will be lifted, and thus the two side rods, *J*, will be raised. The outer end of *T* is fastened to the governor rope; hence, if the speed of the elevator car becomes great enough to cause the governor to act and stop the motion of the rope, *T* will be lifted and so will the rods, *JJ*. The castings, *SS*, at the ends of the safety plank, shown in the lower part of Fig. 101, and also in Fig. 103, are massive, and have a tapered recess on the side where the rods, *J*, are located. When the car is running under normal conditions a hardened steel roller rests at the bottom of this recess, being held in place by the hooked end of rod, *J*. If the speed increases sufficiently to cause the governor to act, and thus lift the rods, *JJ*, the rollers

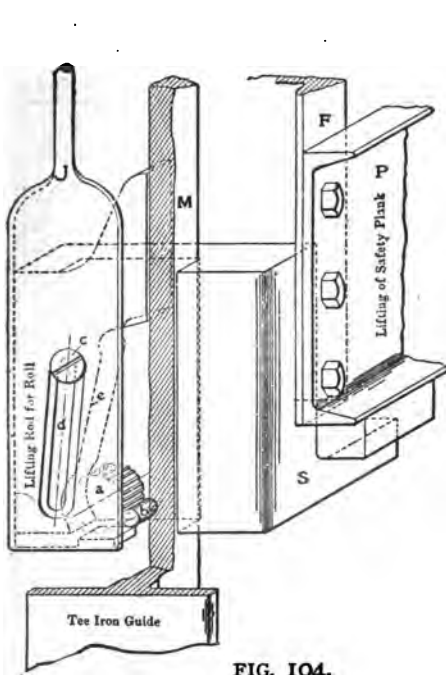


FIG. 104.

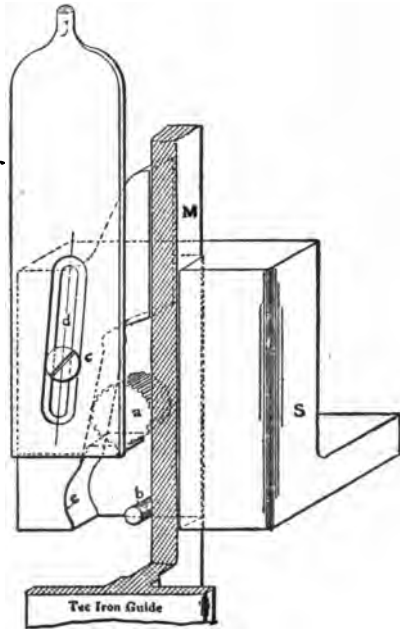


FIG. 105.

will be raised until they catch between the side of the guide, *M*, and the side of the recess in *S*, and they will then be carried by their rotation further into the taper space, until they are wedged so tight as to bring the car to a standstill.

Construction of the blocks, *SS*, and position as well as shape of the recess in which the steel roller is contained are shown in Figs. 104 and 105; the first one showing the position of the roller, *a*, and the lifting rod, *J*, normally, and the second, their position when the governor has acted and the roller, *a*, has been raised into the active position. The

stud, *b*, is provided to hold the roller away from the guide, *M*, under normal conditions. The lower end of *J* is guided by the screw, *c*, which runs in a groove, *d*, cut at such an angle that the hook end will not be brought into contact with the surface, *e*, when the roller is lifted to the active position, as shown in Fig. 105.

As can be readily understood, the strain tending to burst block, *S*, is very great when *a* goes into action, and, on that account, *S*, is made

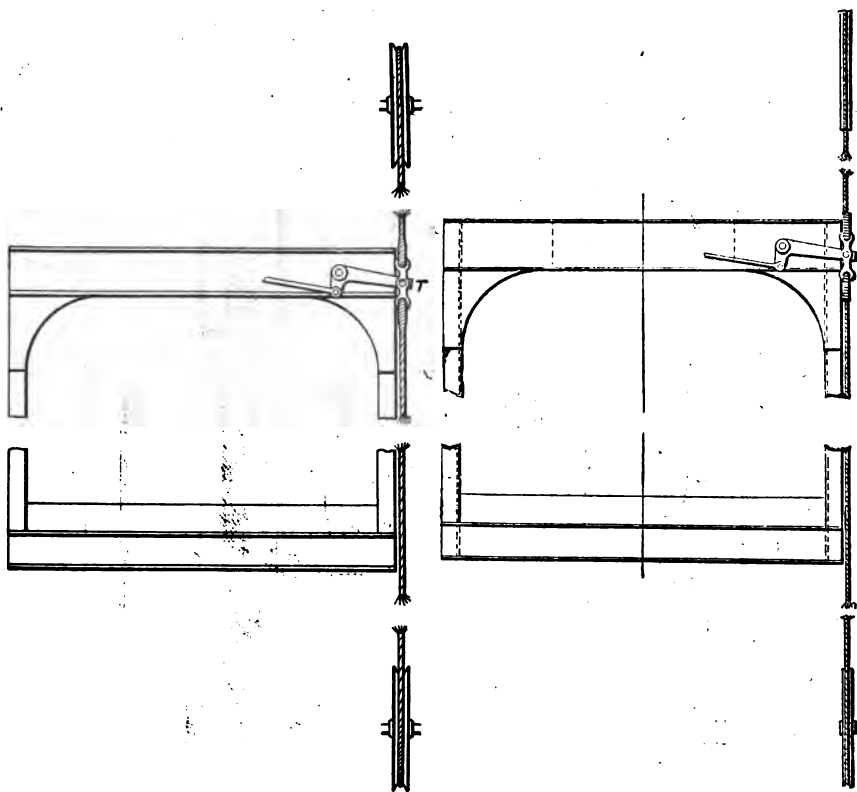


FIG. 106.

extra strong, and in addition is reinforced by the flanges of the side bars, *F*, as is clearly shown in Fig. 103.

In the upper part of Fig. 101 it will be noticed that the connecting rod, *H*, is surrounded by a spring, *K*, at one end. This spring presses against the end of the rod on the right side and against a stationary abutment, *L*, on the left side, and being under compression, forces the levers, *N*, downward. The spring, *K*, is made stiff enough to resist all slight pulls on the governor rope due to irregularities in friction, etc.,

so that there is no danger of the rods, *J J*, being lifted, thereby throwing the rollers, *a*, into action, unless the rope is actually caught by the grip jaws of the governor. The way in which the governor rope is connected with the end of lever, *T*, is clearly shown in the simplified drawing, Fig. 106, the upper wheel being the governor wheel.

This safety device is actuated wholly by the safety governor, and, if either one of the lifting ropes, *A A*, were to break, the car would not be stopped. This, however, is not a defect, because, as the device is actuated by the velocity of the car, it would come into action, if after one rope broke the remaining one should prove insufficient to hold the load and should give away also. Immediately upon the parting of the second rope, the device would come into action, because the increased speed of the car would accelerate the velocity of the safety governor and cause it to grip the rope and lift the end of lever, *T*.

In freight elevators only two lifting ropes are used, so that, if one should break, there might be danger of the second one following suit, if the load were extra heavy; but passenger elevators always have from four to six ropes, so that, if one gives way, there is small probability of any of the remaining ones following suit. The principal objection to a safety device that does not act when one of the ropes breaks is, that it permits the car to run with a loose rope dangling down in the elevator well, and this may become caught in some part of the apparatus and do considerable damage before the elevator is stopped.

If the safety will act as soon as one of the ropes breaks, the car will be immediately stopped and so will the elevator machine, because there is another safety device provided that stops the machine, if, for any reason, the lifting ropes become slack; and, as can be seen, if the safety on the car should come into action and stop the car, the lifting ropes would at once slack up, and thus bring the slack cable stop into action.

By a slight modification the arrangement shown in Figs. 101 to 103 can be made so as to come into action when a rope breaks, as well as when the speed becomes great enough to cause the safety governor to act. A safety of this kind is shown in Figs. 107 and 108, both of which show the upper crosshead of the car-supporting frame, the former figure being a top view and the latter a side elevation. Looking at Fig. 108, it will be seen that the lifting ropes, *A A*, are secured to bolts, *B B*, that pass through blocks provided with swivel bearings at the ends, these being marked *C*. The ends, *C*, pass through holes in side bars, *D*, as is more clearly shown in Fig. 107. One of these *D* bars has its ends bent outward so as to project over the levers, *F F*. These last named levers swing around the studs, *K K*, and their outer ends hold the side rods, *J J*. The governor rope, *H*, is connected with the end of one of the *F* levers.

by means of an arm, *N*, shown in Fig. 107. The two *F* levers are connected at their inner ends by means of a pin made fast in one and arranged to slide in a slot in the other, as is clearly shown in Fig. 108. From this it will be seen that when the governor rope, *H*, lifts the end of the lever, *F*, with which it is connected, the center ends of both levers will be depressed and thus the outer end of the other *F* lever will be lifted and in that way the two *J* side rods will be raised. The bars, *D*, swing around the stud, *E*, so that, if one of the ropes, *A*, breaks, the end of *D* on the same side will be forced downward and will strike one of the *F* levers and depress it, thereby lifting the rods, *J J*. The spring, *L*,

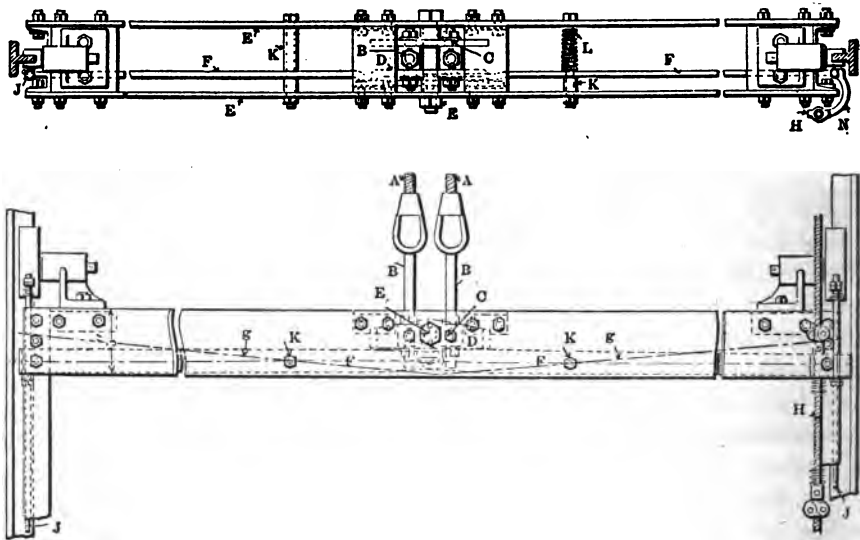


FIG. 107.

FIG. 108.

placed around one of the studs, *K*, acts to swing the levers, *FF*, into the position in which they are drawn. When they are lifted, either by the action of the governor rope, *H*, or by the downward movement of one end of the *D* bars, they are carried into the position indicated by the lines, *g g*.

The drawings show a safety arranged for two lifting ropes; if there were four ropes and two were passed through each one of the blocks that swivel around the studs, *C*, the bars, *D*, would not be depressed at one end unless both the ropes attached to one of the blocks gave away. To make the device operative with four ropes, however, all that is necessary is to provide short crossheads attached to the upper ends of the bolts, *B*, by means of a swivel joint, and then one rope can be secured to either

end of each crosshead. With this construction, if one of the ropes breaks, the bolt, *B*, with which it is connected will drop down and thus permit bar, *D*, to swing around *E* in precisely the same manner as with the two-rope construction.

These designs, shown in Figs. 101 to 103 and 107 and 108 can be used with other clamping devices, as well as with the roller. If the elevator runs on hardwood guides, they can be used with the wedge safety or with the triple grip. It is obvious that iron guides cannot be used with the triple grip safety, and the results are not likely to be entirely satisfactory with the wedge safety. The first impression with regard to the wedge is that, if it is drawn up with a moderate force, it will bind so tightly against the guide as to surely hold the car, but experience has shown that, unless the force with which it is pushed upward or held from moving downward is quite considerable, the pressure against the guide will not be sufficient to keep the wedge from sliding.

When the guides are of hardwood, the pawl that lifts the wedge digs into the side of the guide and thus forms an abutment against which the lower end of the wedge presses, so, that, as the wedge cannot move further down, the car rides over it and thus develops a sufficient pressure to hold the weight. It is true that by giving the wedge a sufficiently long taper it can be made to wedge in tight enough between the guide and the jaws of the safety plank not to slide down, but if it is made of such a taper it becomes very difficult to free the car whenever it is caught, and, furthermore, unless the jaws in the safety plank are made of wrought iron and massive they are very likely to be forced apart by the pressure of the wedge. The roller is far more positive than the wedge because, as soon as it is caught, it begins to roll upon the surface of the guide and the side, *e*, Fig. 104, of the clamping block and there is no tendency whatever to slide.

It will be noticed that the shoes that guide the car are not of the same design in Figs. 101 and 108, those in the first illustration being solid, while those in the last are in two parts, one being the shoe proper and the other its support. The latter construction is the more desirable for high-speed elevators, as it prevents side sway of the car and conduces to smoother running.

## CHAPTER XVI.

## ELEVATOR SAFETY APPLIANCES; BRAKE TYPE.

**W**EDGE and roller safeties, as heretofore described, bring the car to a standstill abruptly when they come into action. With the roller device, the motion of the car is arrested within 2 or 3 inches. The wedge safety will not produce so sudden a stop because the dog that throws the wedge into action will shave down the side of the guide for a distance that may vary between 6 and 15 inches, and the wedge and car will descend as far as the dog goes. The triple grip safety permits the car to descend still further before coming to rest. With slow-running elevators, a safety that stops the car suddenly can be used successfully because the safety governor can be set to act at a low velocity, so that the practically instantaneous stoppage of motion is not objectionable, considering that it has to be contended with only when something goes wrong with the apparatus.

With fast-running elevators, however, a sudden stop may be dangerous, owing to the fact that the governor must be set to act at a high velocity; hence, in such cases, it is desirable to use a form of safety that will arrest the motion gradually. The triple-grip device accomplishes this result in a satisfactory manner, but as it can be used only with hardwood guides, it is not available for high buildings in which iron guides are provided. For such an installation the most approved type of safety is actuated upon the principle of a brake that goes on with a light pressure at the beginning, which is gradually increased until the frictional resistance becomes sufficient to arrest the motion of the car. This device is known as the clamp safety, and is shown in one design in Figs. 109 and 110, this being the construction used by the Otis Elevator Co.

Fig. 109 is a plan and side view, and Fig. 110 an end view of the plank. The jaws that form the brake clamp swing around a bolt, *A*, and are forced against the sides of the guide by means of the toggle links, *B*. Under the center of the car, a drum is placed around which is wound a hemp rope that is attached to the governor rope. When the latter rope is caught by the clamping jaws of the governor, it pulls on the rope wound around the drum of the safety and thus rotates this drum. The rods upon which the drum revolves are threaded right and left hand, so that, as the drum revolves, it forces the rods out endwise and thus spreads the toggle links, *B*, and opens the inner ends of the brake jaws. The further the elevator car descends after the governor rope has been caught, the more the safety drum is revolved and the tighter the

brake jaws press against the sides of the stationary guides, until the force becomes sufficient to stop the descent of the car.

At one end of the safety drum, a flange is provided into which a number of holes are drilled so that should the device be called into action at any time the drum can be turned backward to its normal position by inserting a bar in these holes. The brake clamps are made to run with as small a clearance between them and the guide as is practicable, and on that account the total movement required of the toggle

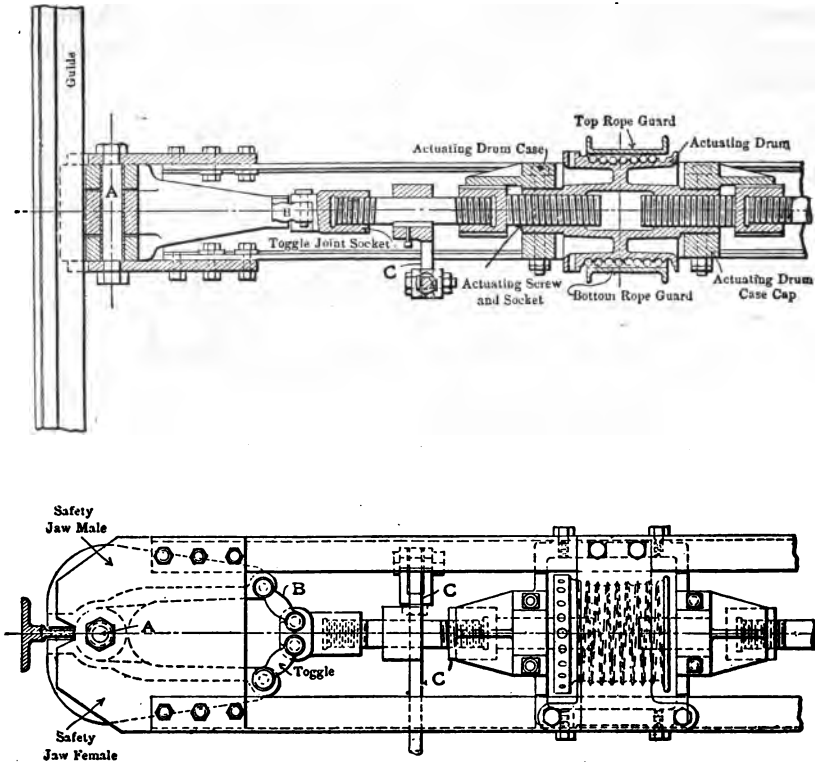


FIG. 109.

jaws to put the brakes on with sufficient force to hold the car is small, so that the pitch of the threads cut on the ends of the rods around which the drum revolves is small. To put the brakes on with sufficient force to hold the maximum load that the car can carry requires about two and one-half turns of the drum.

The lever, *E*, shown in Fig. 110, is provided as an emergency device to enable the operator in the car to apply the brakes, if for any reason the drum fails to do the work. The lower end, *D*, of this lever is con-

nected with lever, *C*, by means of the connecting rod, *C'*. As is shown in Fig. 109, *C* is fastened to a short rod threaded at both ends, one end screwing into the casting that holds the toggle links, *B*, and the other end into a nut that is kept from turning by the overhanging top of the actuating drum case. The form of this nut is clearly shown in Fig. 110. The threads on the ends of this short rod are of a much greater pitch than those cut on the ends that pass through the drum, so that one-quarter turn is sufficient to spread the toggle jaws as far as is required to develop the full braking force. To swing lever, *E*, through the one-quarter turn, lever, *E*, has to move through 60 degrees, reaching the position *E'*.

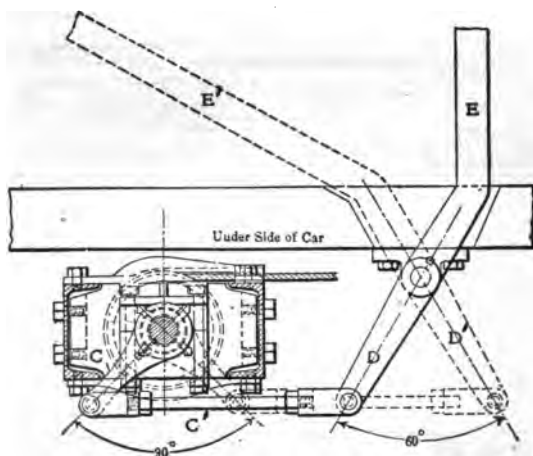


FIG. 110.

The way in which this safety is connected with the safety governor rope is clearly shown in Fig. 111. The clamp at the top of the elevator car grips the governor rope with sufficient force to prevent its slipping under ordinary conditions, but when the governor goes into action and its grip catches the rope, the car clamp is unable to hold it, and as a result the safety drum rope is unwound and the brakes go on and bring the car to a stop in a distance that may be anywhere from one and one-half to two and one-half times the circumference of the safety drum, according to the weight in the car at the time.

Another design of toggle clamp safety which is made by the Morse-Williams Co. is shown in Fig. 112. As will be noticed, it is quite different in the details of construction from the Otis design, although the principle of action is the same. The drum guards used in the Otis design are omitted, and so is the emergency lever, *E*. In place of

the latter the bevel gears, *K* and *L*, are provided, the latter being mounted upon a short vertical shaft which terminates in an end, *M*, formed to receive a socket wrench which is inserted by lifting the floor plate above *M*.

This device cannot be used in the same manner as the emergency

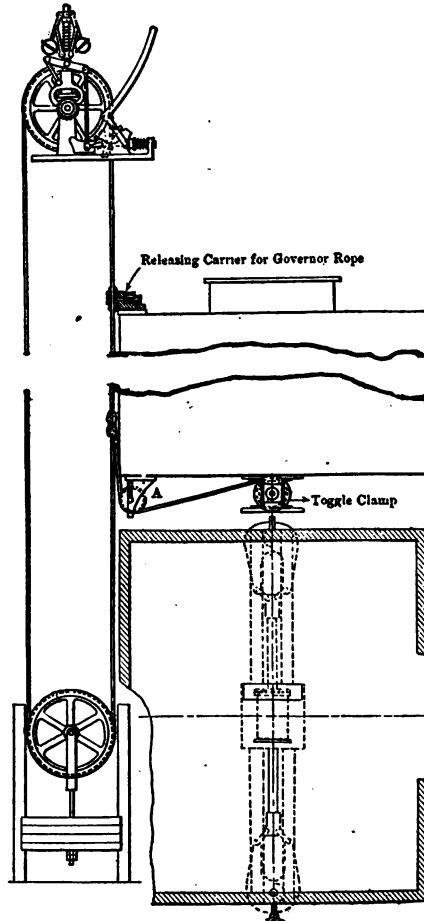


FIG. III.

lever, *E*, and is intended simply to provide means for releasing the brake after it has gone into action. The way in which the toggle jaws are held and operated is also different from the first described design. In place of the swivel stud, *A*, the curved bearings, *aa*, are provided, and the jaws are held from spreading by means of three bolts, *H*. The inner ends of the toggle clamps, *AB*, are forced apart by drawing the

wedge, *E*, between the ends, *D*, and springs, *J J*, are provided to press the ends, *D*, together when the clamps are in the normal position. The

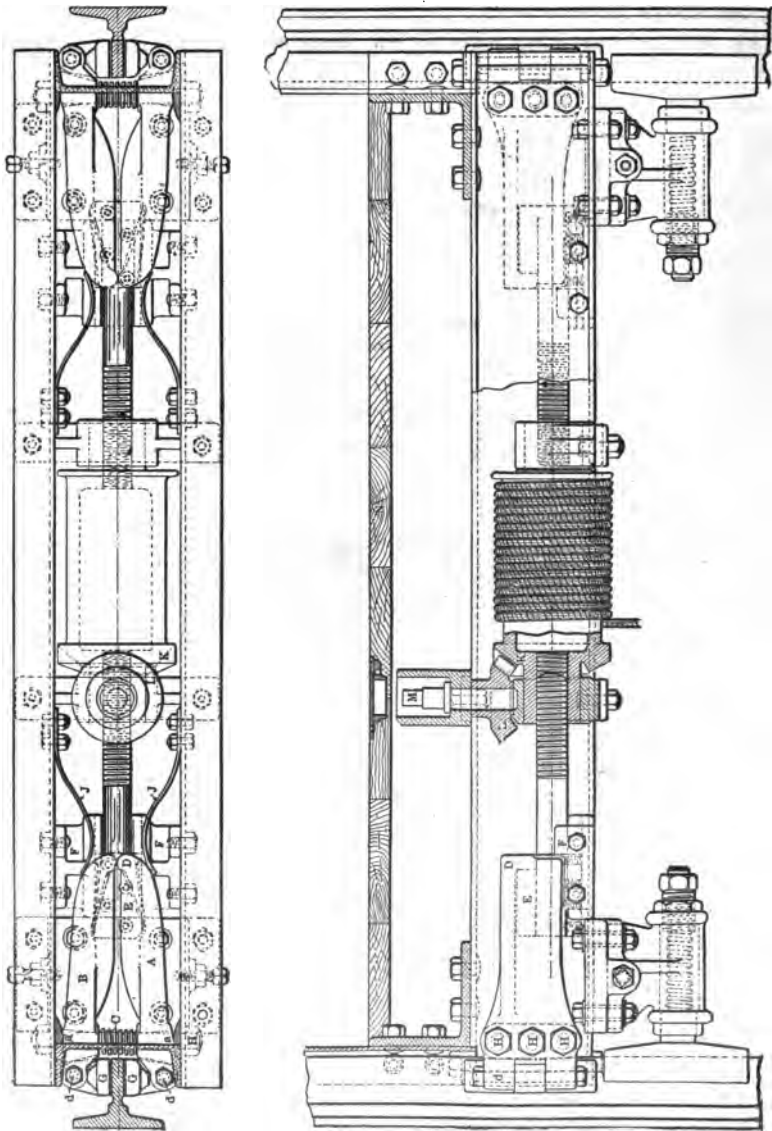


FIG. 112.

brake shoes proper, which are marked *G G*, are pivoted at *d d* for the purpose of permitting the shoes to press evenly over the whole surface of

the guide. The spring, C, acts to hold the clamping jaws apart so that they may not rub against the guides.

In Fig. 112 the regular guide upon which the elevator car runs is drawn directly under the safety plank. In the Otis design shown in

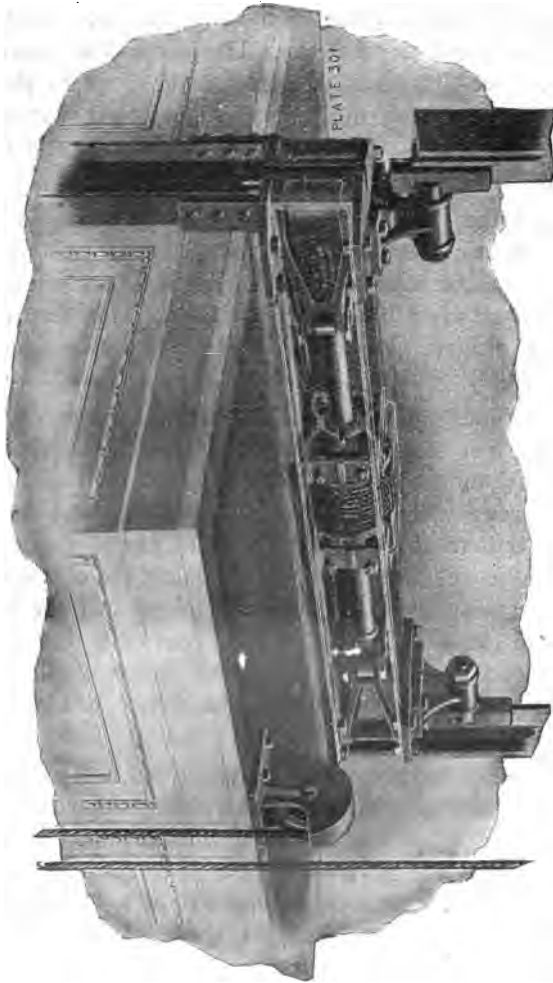


FIG. 113.

Figs. 109 and 110 no guide is shown, but they are provided in practice, and the brake shoes do not perform the duty of guides as well as a safety device, as might be inferred from an inspection of the drawing. As a matter of fact, it would not be advisable to permit the brake shoes to come in contact with the stationary guides, because, as they must

have a small clearance, the amount of wear they would be subjected to, if they rubbed against the guides, would soon increase the clearance to such an extent that the safety drum would have to rotate through a greater number of turns than is advisable to apply the brakes with full force.

Fig. 113 is a half-tone illustration showing the Otis clamp safety in position under a passenger elevator car. The lower drum guard and the front chanel beam are drawn as if transparent, so as to show in full outline the working parts of the safety. The lower car guides are attached to the under side of the side beams, the same as in the Morse-Williams design.

One feature of the clamp safety that makes it desirable for use in connection with electric elevators, and with some forms of hydraulic machines is that it can be readily arranged so as to act when the car is running up as well as when it is running down. This feature is really indispensable with electric elevators of the drum type, which is now used almost exclusively.

With such machines, the weight of the elevator car is over-balanced, so that, if the elevator is running up with a light load, the balance weight actually lifts the car, and if, while ascending under such conditions, anything should go wrong with the hoisting apparatus, the balance weight would drop to the bottom of the building and the car would be shot up to the top of the elevator well and would strike against the overhead framing with such force as probably to do serious damage. If the load in the car were great, the car would drop, in the event of a runaway, and, in that case, the safety would have to come into action on the down trip, while with a runaway with a light load, the device would have to act on the up trip.

To make the clamp safety act on the up trip as well as on the down trip, all that is necessary is to provide two guiding sheaves, *A*, Fig. 111, for the safety drum rope, so that the rope will be pulled and the drum unwound whichever way the governor rope may be running. In addition to this change, the governor must be arranged so as to be double acting—that is, so as to grip the rope when the speed exceeds the limit, no matter in which direction it may be running.

A double-acting safety governor, of the type used to hold the car on the up as well as the down motion, is shown in Fig. 114. With this governor, if the rope is running downward on the left-hand side, the clamp at *A* will come into action and grip the rope, while, if the rope is running in the opposite direction, the clamp at *B* will grip it. This governor acts upon the same principle as the single-acting governor that

was described in a previous chapter; therefore, it need not be explained in detail here.

Figure 115 illustrates the construction and operation of the Pratt clamp safety. In this safety there is a strong spring at *M* which is held

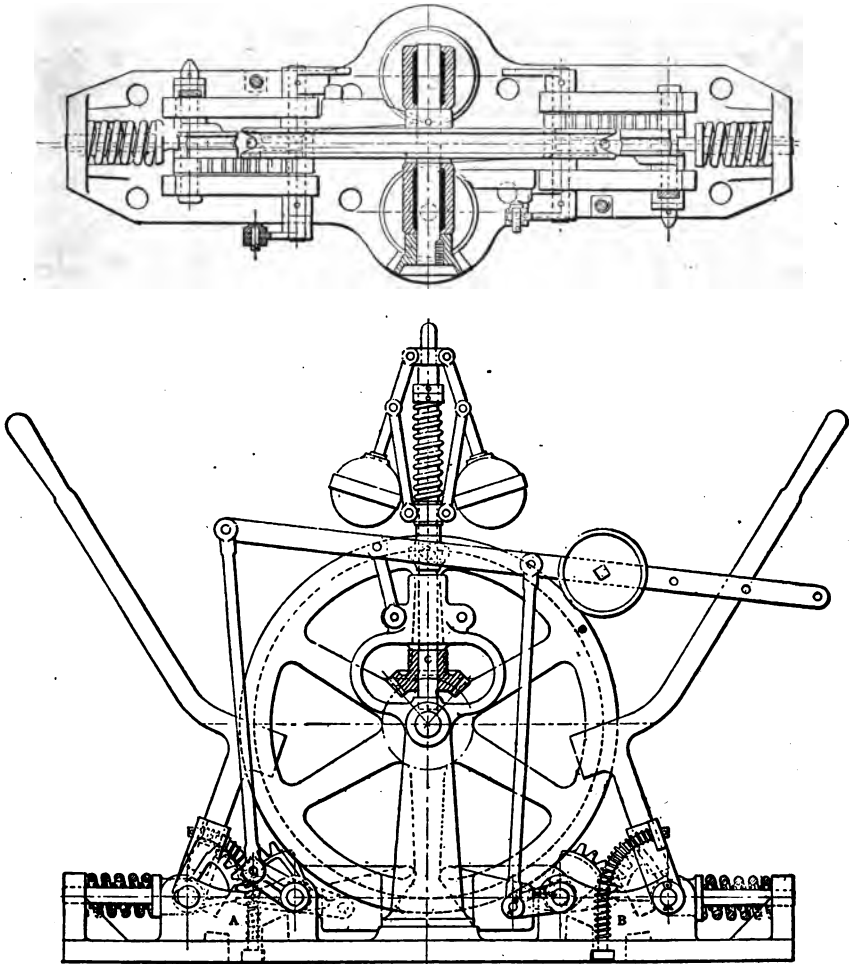


FIG. 114.

compressed by the catch, *K*. When the drum, *C*, is rotated by the governor rope, the end of shaft, *D*, pushes bar, *J*, to one side and thus opens the latch, *K*, and then the tension of spring, *M*, throws the side levers into the position of the middle view and draws the rollers, *R*, toward each

other, thus forcing the clamps, *X*, against the guides, *U*. The continued rotation of drum, *C*, draws the nuts, *H G*, toward each other and thus increases the pressure of the clamp upon the guides.

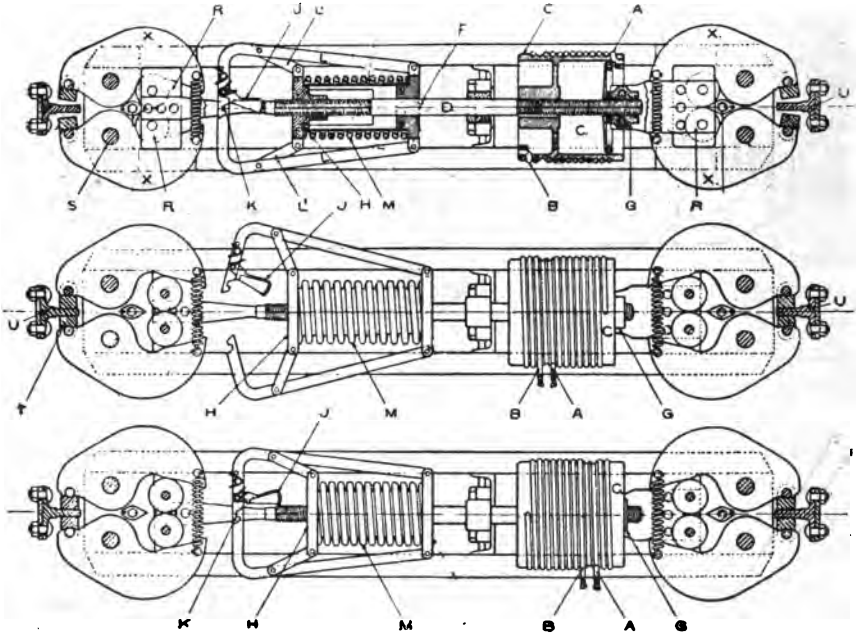


FIG. 115.

This form of clamp will bring the pressure of the clamps upon the guides more gradually than if the spring, *M*, were not used; hence, the stopping of the car will be more gradual.

## CHAPTER XVII.

## ELEVATOR SAFETY GOVERNORS, CENTRIFUGAL TYPE.

**G**OVERNORS described in previous chapters are similar to those on steam engines, are mounted on top of the overhead framing that supports the sheaves over which the lifting ropes run, and are driven by an endless rope that is attached to the elevator car and therefore moves at the same velocity. Safety governors are also made to be mounted directly upon the elevator car, generally on top of it, and are driven by a stationary rope which is secured to the top and bottom of the elevator well. A governor of this kind is shown in Figs. 116 and 117, arranged to actuate a safety of the roller type.

At *N* is shown the governor proper, consisting of a casing having a

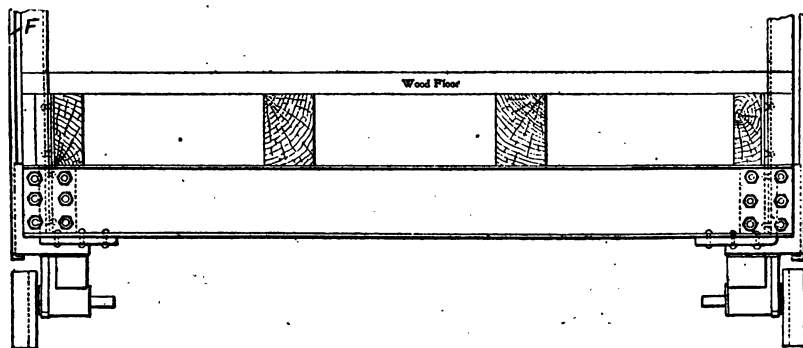


FIG. 116.

grooved wheel formed at its edge, and a weighted lever within the casing which is held against the center hub by the tension of a spring, and is forced outward by centrifugal force, in the same manner as the flywheel governors used on engines.

Side lifting rods, *FF*, that raise the rollers into the active position are held by the levers, *E*, mounted upon the rock shafts, *G*. The two rock shafts, *G*, at either side of the car are connected with each other through the levers, *HH*, and connecting rod, *I*, the spring, *J*, acting to move *I* toward the right and thus to lift levers, *EE*. On one of the *G* shafts a short lever, *K*, is provided which engages with the upper end, *L*, of a cam lever that is actuated by the governor.

The governor is driven by the rope, *Q*, which passes over the sheave, *P*, located at the left side of the car and under the governor, *N*. The end of the rope passing up from the right side of the governor goes to

the top of the elevator well, where it is secured to the overhead framing. The other end which passes down from the left side of sheave, *P*, runs to the bottom of the elevator well, where it is secured so as to be at all times under proper tension to prevent slipping around the governor, and also to have a sufficient vertical movement to compensate for expansion, but it cannot be displaced laterally. The sheave, *P*, is placed so as to lead the rope down in the space between the side of the car and the elevator well, but the governor, *N*, can be located at any point where the construction of the other parts of the apparatus may require, as there is nothing to interfere with the position in the elevator well of the governor rope above the car.

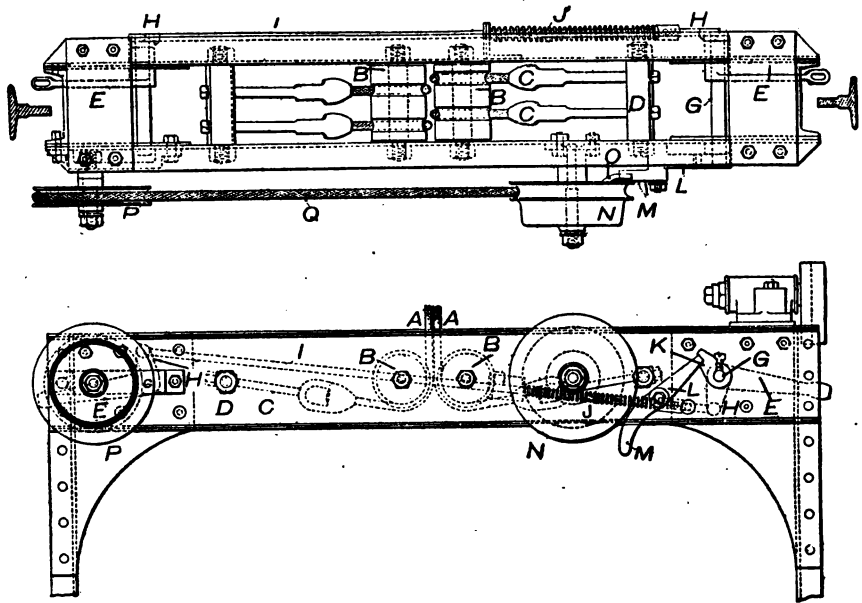
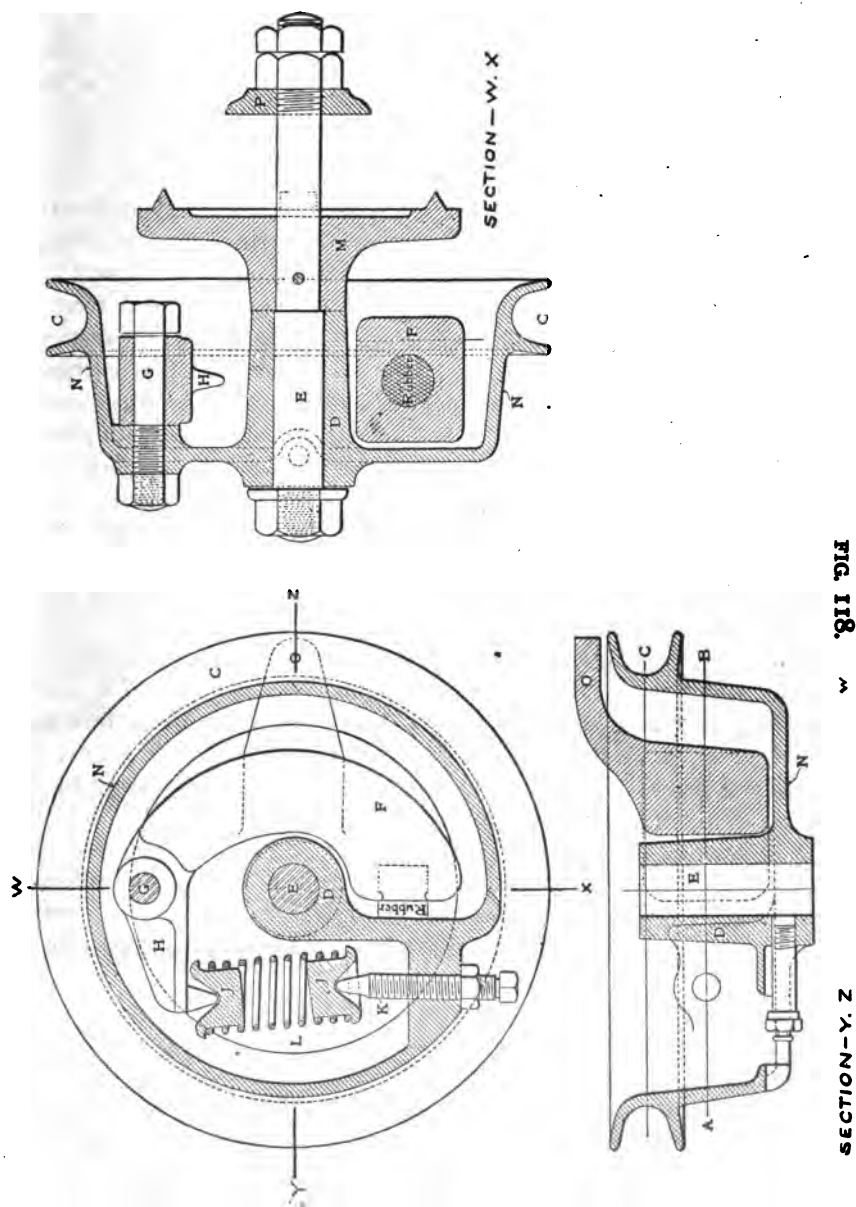


FIG. 117.

As the rope, *Q*, is stationary, it can be seen that, the faster the car moves, the faster the governor will revolve; hence, by setting the latter so as to act at any given speed, the safety can be made to go into action when the car velocity is such as will develop this speed. In Fig. 117, it will be seen that an arm, *O*, projects from the back of the governor and is in line with the end, *M*, of the lever that holds *K* in the inactive position. This arm, *O*, is attached to the governor weight and swings out from the center with the weight.

When the velocity of the governor becomes sufficiently great, the arm, *O*, swings out far enough to strike *M* and knock the end, *L*, of this



lever out of engagement with *K*. As soon as this occurs, the spring, *J*, forces rod, *I*, and levers, *H H*, to the right and thus the side rods, *F F*, are lifted and the safety rollers are thrown into action. It can be seen readily that as *O* moves out from the center gradually, the first time it strikes *M* it will not move it far enough to allow *K* to drop, but at each succeeding revolution *O* will swing further from the center because whenever it moves out far enough to strike *M* it is because the car has attained a velocity exceeding the normal, and this velocity is constantly increasing, so that the governor speed is constantly increasing, and on that account at each revolution *O* swings further from the center.

From this it follows that the first blow struck on *M* by *O* will generally move *L* only a portion of the distance required to free it from *K*. The second blow in all probability will move *L* the balance of the distance. If the rock shafts, *G*, the ends of *L* and *K* or the stud that carries *L* should be stuck fast by reason of neglect to keep them in proper condition the arm, *O*, will strike blow after blow on *M*, each blow with greater force than the previous one, and, unless the parts adhere to each other with far greater tenacity than is at all likely to be the case, *K* will eventually be released and the safety will go into action. This principle of releasing *K* by striking successive blows is a good one because the jar produced by the blows acts to shake loose all the joints and thus insure their movement as soon as *L* is moved out of the way.

The way in which this governor is constructed is shown in Fig. 118 by a horizontal section on line *Y Z*; a section on the line, *A B*, and a vertical section on the center line, *W X*. As is shown in these drawings, the arm, *O*, is an extension of the weight, *F*, which swings around the stud, *G*, and is pressed against the hub, *D*, of the governor casing by the force of spring, *L*, acting against the end, *H*. The caps, *J J*, hold the spring in position between the adjusting screw, *K*, and the point on end, *H*, of the movable weight. The governor revolves around the stationary stud, *E*, which is secured to the side of the car crosshead by means of the flange, *M*, washer, *P*, and the nuts shown. The driving rope runs in the groove, *C*.

This type of safety governor can be used with the wedge, the roller or the triple grip safety, but not with the clamp safety, because for the latter the action must be such that the rope which rotates the safety drum will continue to unwind until the car comes to a stop, and this result cannot be obtained with this governor, which only acts to trip a catch that holds the safety actuating levers in the inactive position.

Figures 119 and 120 show a stationary governor made upon the same principle as the one just described, with the exception that it has two weights and is therefore balanced. As shown in Fig. 119, the governor

consists of a wheel mounted upon a shaft, *J*, and carrying two weighted arms, *AA*, pivoted at *PP*. The short ends, *O*, of these arms, press against the ends, *N*, of a piece, *M*, which is held in position by means of the spring, *K*, shown in Fig. 120. The torsional resistance of this spring acts to hold *M* in position, and the centrifugal force of the arms, *AA*, acts to move it out of position. By twisting *L* around the shaft, *J*, the force of the spring can be adjusted so as to permit the arms, *AA*, to swing out at any velocity desired. When the arms swing out, the extreme ends follow the curves, *B*, and the projections, *C*, follow the curves, *D*, thus providing four points on the circle to catch the projection,

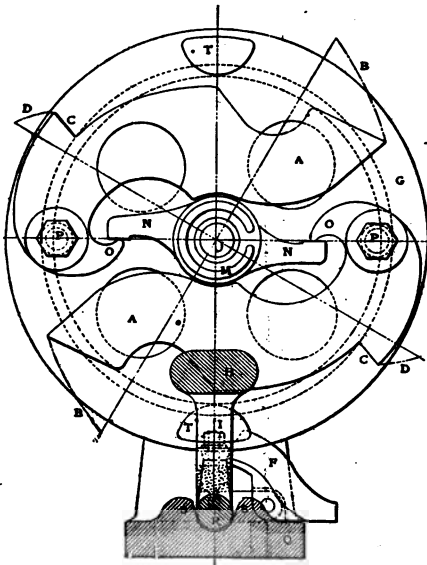


FIG. 119.

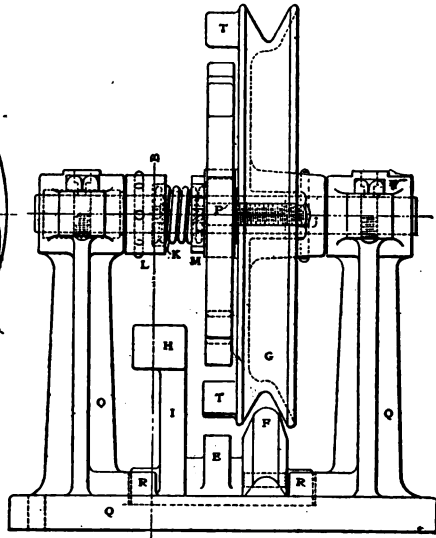


FIG. 120.

*E*, Fig. 120, and throw the brake shoe, *F*, up against the groove, *G*. The stops, *TT*, act as abutments against which *AA* are held so as to not be forced beyond a certain distance from the center, either by centrifugal force or by striking against *E*. The weight, *H*, on the end of arm, *I*, acts to hold *F* up against the wheel after it has been thrown into action by the arms, *AA*. As shown in Fig. 120, the arm, *I*, and the projection, *E*, are both cast in one piece with trunnions, *RR*, that rock in the depressions formed in the frame, *Q*, by the projections, *SS*.

This type of governor is driven by a hemp rope, and is used in connection with the wedge, the roller and the triple grip safeties, but not with the clamp brake safety. It cannot be used with the latter because

the driving rope is held by the friction against the groove *G*, and while this can be made sufficient to hold the rope under ordinary conditions by properly shaping the groove it is not reliable enough to be depended upon. The governor can be used in connection with a clamp safety by setting it in the inverted position, so that the brake shoe, *F*, will wedge the rope against the bottom of the groove in the wheel. In that case a spring, as is shown in broken lines in Fig. 119, is provided to hold *F* in position against the rope, and the weight, *H*, is removed.

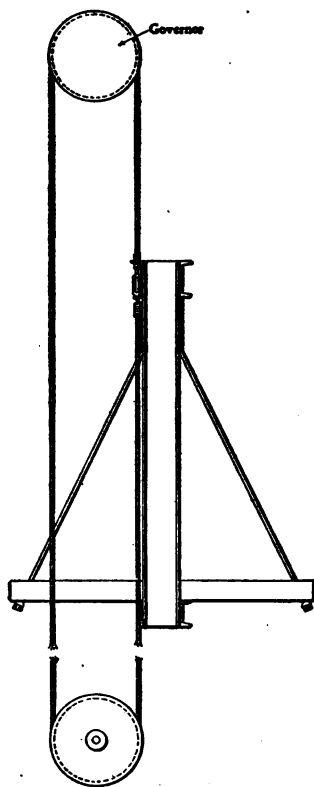


FIG. 121.

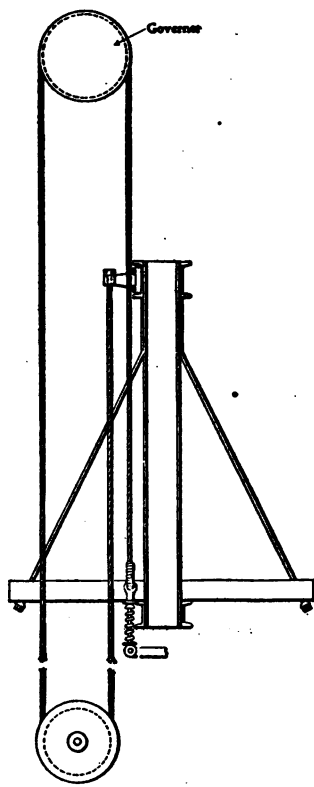


FIG. 122.

This type of governor is connected with the elevator car for actuating the roller and triple grip safeties as shown in Figs. 121 and 122. The first figure shows the connection for operating the roller safety, and the second is for the triple grip device. In one case, both ends of the governor rope are fastened to the safety lever, but in the other, one end is made fast to a rigid support on the car frame and the other end is connected with the safety lever. This latter connection is not so likely

to throw the safety into action by any sudden movement, as a portion of the strain developed by the resistance to motion of the governor and the lower sheave is taken by the stationary support or dead hitch, as it is called. Owing to this fact the device can be made more sensitive in its action than when the connection is as in Fig. 121.



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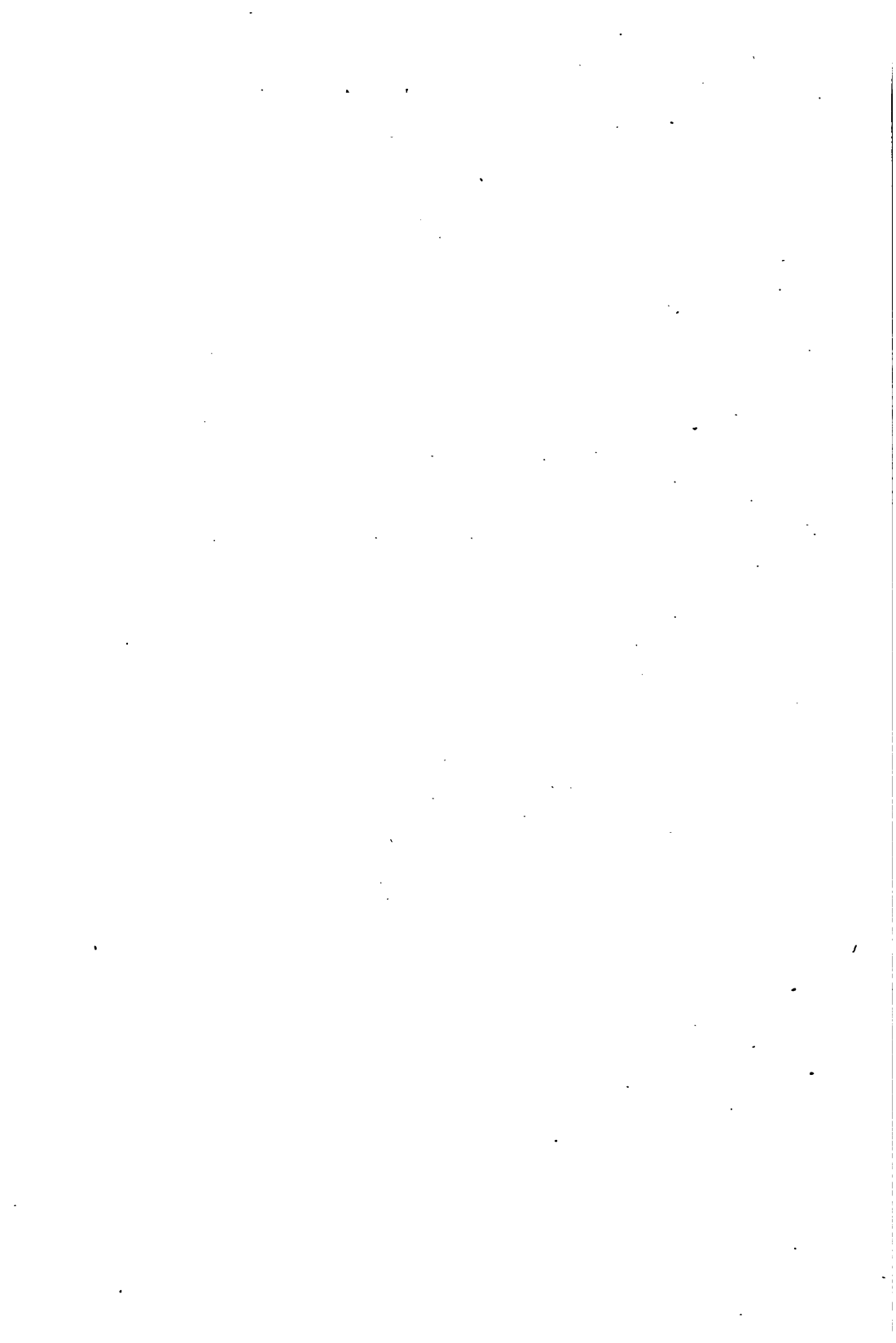
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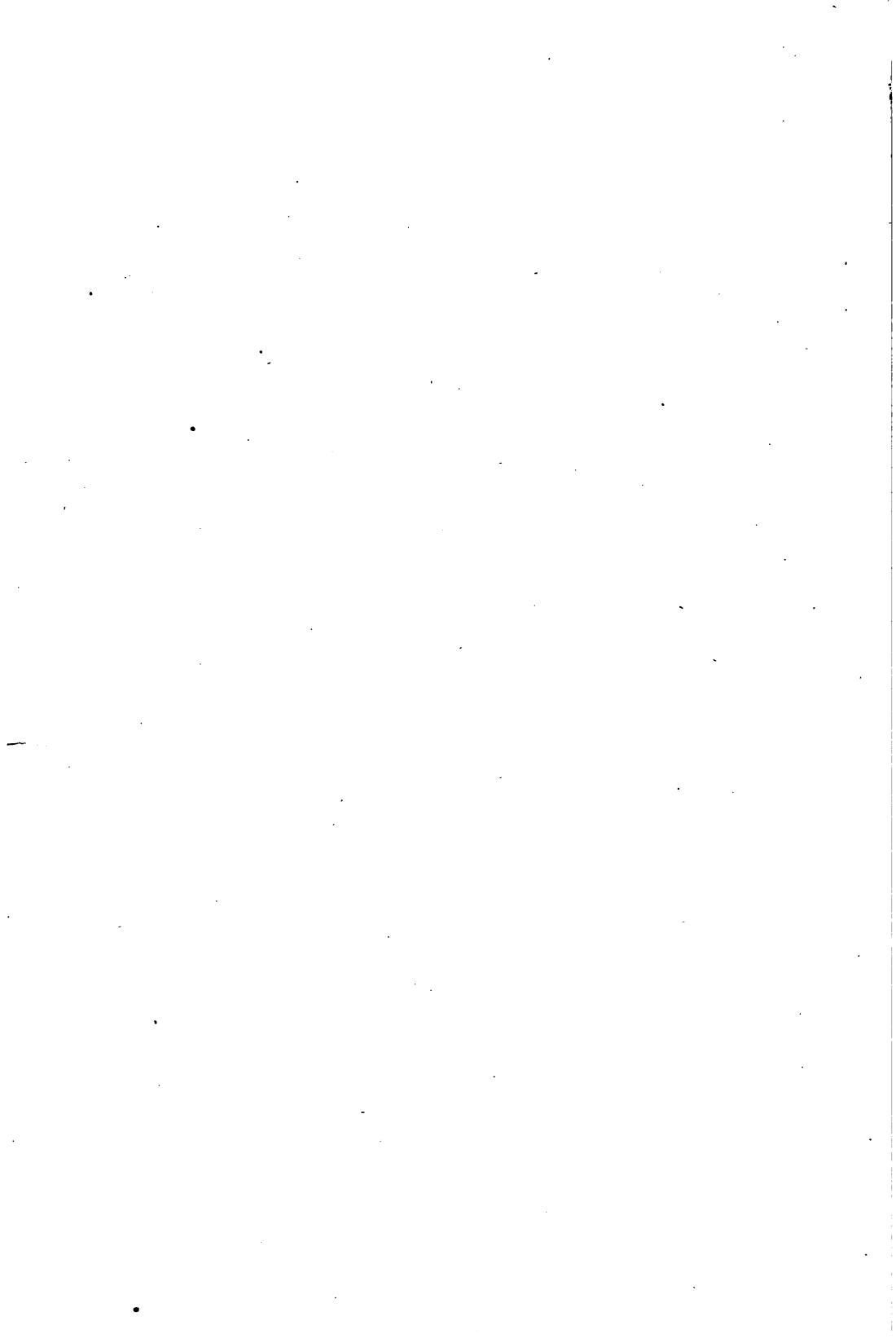
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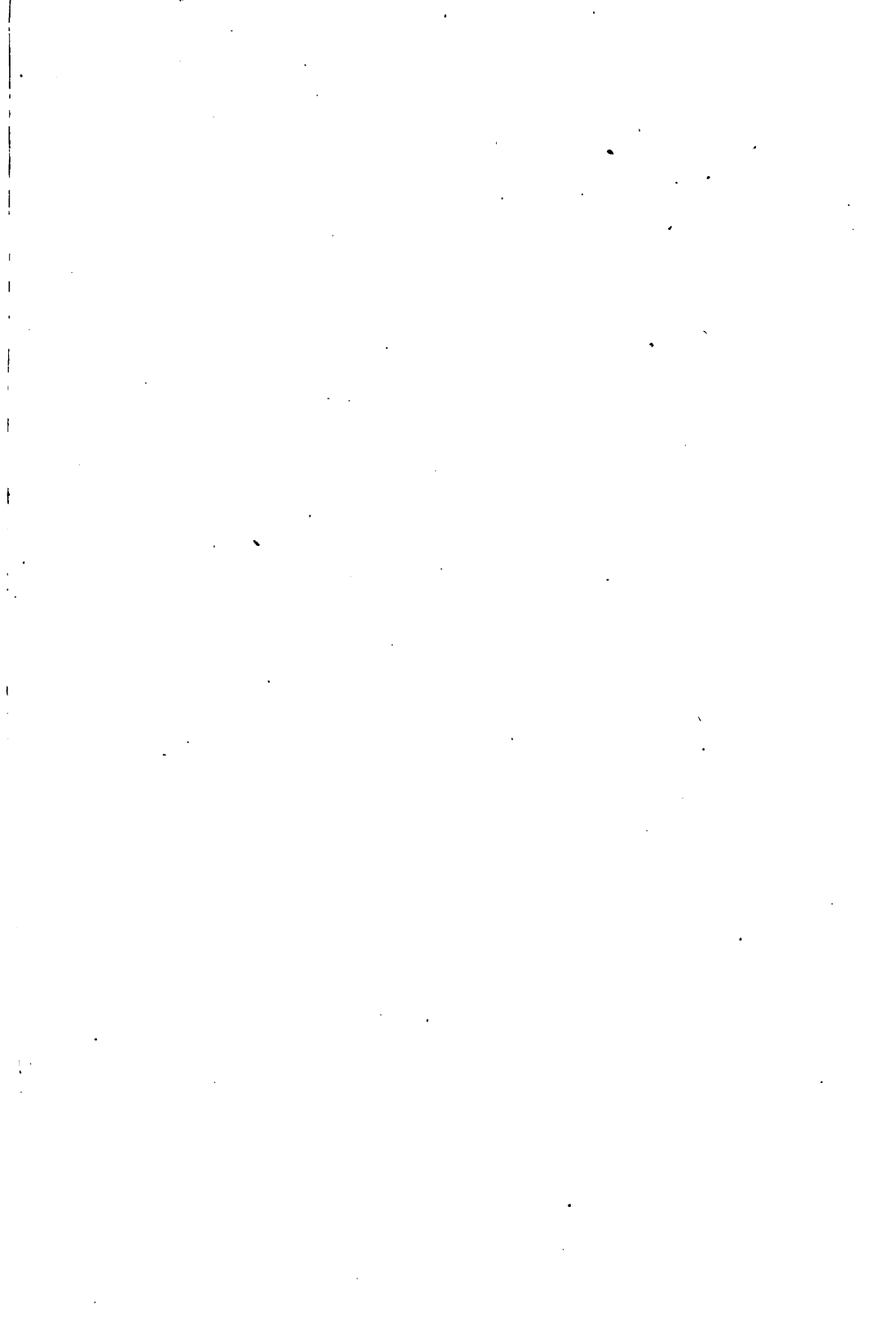








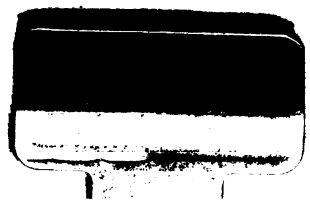
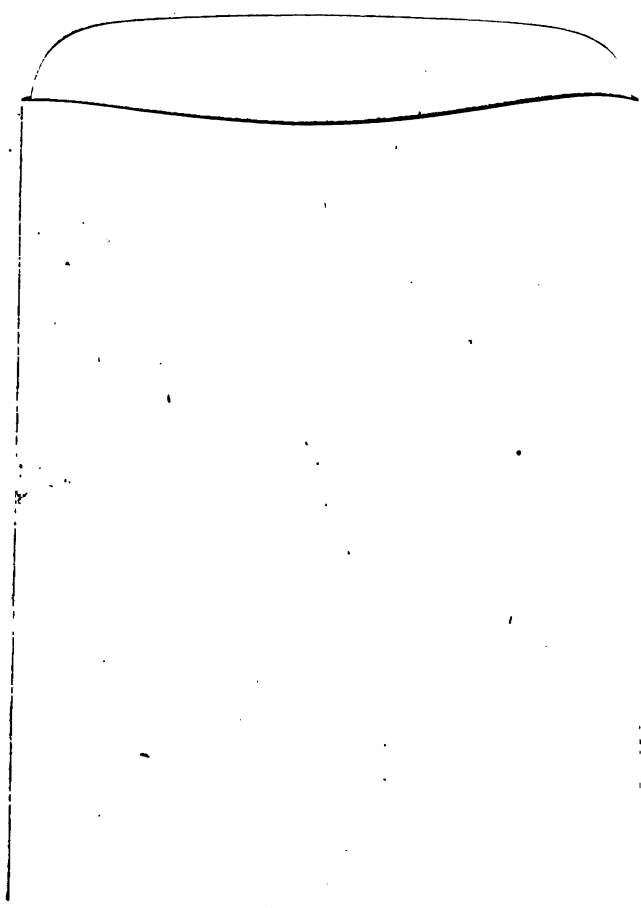




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